EXTRACTING MISSION SEMANTICS FROM

UNMANNED AERIAL VEHICLE

TELEMETRY AND FLIGHT PLANS

THESIS

AFIT/GCS/ENG/00M-01

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Degree of Master of Science in Computer Systems

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Walter T. Berridge

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ABSTRACT

With the acceptance of Unmanned Aerial Vehicles (UAVs) as a primary platform within the Department of Defense (DOD) for gathering intelligence data, the amount of video information being recorded, analyzed, and archived continues to grow. Mechanisms for quickly locating and retrieving video segments of interest amongst the many hours of recorded video are required to accommodate the rapid turnaround expected in today's wartime planning environments. This research demonstrates that text-based data accompanying UAV video yields sufficient information to identify and create data items that can be indexed to provide for rapid identification and retrieval of video segments of interest. Four attributes are derived or calculated from mission-related telemetry and target data: look-direction, look-distance, zoom, and solar illumination direction. These attributes provide indicators of potential scene content and image quality thus allowing analysts to select the *best* (clearest, most detailed) images of a target or target area. A relational database and two tools, a query and profile tool, are implemented to store the data and provide for the retrieval and presentation of video segments to the user. An analysis of the results shows the methodology to be favorable for locating and retrieving video segments of interest. Several recommendations to enhance the methodology are provided at the conclusion of the paper.

EXTRACTING MISSION SEMANTICS FROM UNMANNED AERIAL VEHICLE TELEMETRY AND FLIGHT PLANS

1 INTRODUCTION

Battlefield superiority today can be significantly influenced by the availability of real-time or near-real-time information. Commanders can no longer afford long delays in gathering, processing, and disseminating intelligence data; they require immediate and continuous information flow to support a dynamic battlefield. The Joint Requirements Oversight Council recognized the changing nature of warfare and issued the following mission need statement:

> *The warfighting Comanders-in-Chief (CINCs) have a need to provide commanders a responsive capability to conduct wide-area, near-real-time reconnaissance, surveillance, and target acquisition (RSTA), command and control, signals intelligence (SIGINT), electronic warfare (EW), and special operations missions during peacetime and all levels of war against defended/denied areas over extended periods of time. The evolution of the hostile surface-to-air and air-to-air threat and their collective effectiveness against manned aircraft and satellites can generate unacceptably high attrition rates. Current systems cannot perform these missions in a timely, responsive manner in an integrated hostile air defense environment without high risk to personnel and costly systems. There is a need for a capability which can be employed in areas where enemy air defenses have not been adequately suppressed, in heavily defended areas, in open ocean environments, and in contaminated environments. Nuclear survivability is required as necessary to perform missions in a nuclear contaminated environment, including operating in the presence of high-altitude EMP* [ACCCO98].

One of the ways the Defense Department is addressing the changing face of warfare is by employing Unmanned Aerial Vehicles (UAVs) in addition to, or in lieu of, traditional manned and satellite systems. Manned reconnaissance systems are associated with high operating costs and every manned mission places human life at risk. Satellite assets are national assets and may not be visible when the commander in the field needs them. In some instances, satellite assets must be moved into position before they are available to receiving stations, and orbiting satellites suffer from limited exposure at discrete intervals. Satellites also suffer from potentially long delays in processing and disseminating time-critical information to supported commanders.

UAVs, on the other hand, are ideal platforms when near-real-time information is required and when operating in high-threat or heavily defended environments where the potential for loss to high-value manned systems is possible. UAVs can penetrate enemy air space with a low probability of detection and loiter over a target for extended periods of time, day or night, recording imagery in visual, infrared, and numerous electro-optical bands. Their maneuverability and rapid deployment capability means they can support short-notice, ad-hoc planning scenarios.

UAVs currently in operation in the Department of Defense (DOD) are designed to perform either tactical or strategic intelligence missions [CONGR98]. Tactical intelligence provides the brigade commander with the strength, quality, and position of enemy forces just over-the-hill (OTH). The Army's Hunter platform was developed to provide this capability. Strategic intelligence refers to longer-range information gathered by reconnaissance satellites or aircraft or long-range, endurance UAV platforms such as the Air Force's Predator.

To accomplish these varied missions, UAVs are equipped with several types of sensor systems including those capable of providing color and black and white video feed as well as still images. Additionally, full motion video is available in visible, electro-optical, and infrared formats. Given the UAV's ability for long loiter times, there is potential for large quantities of video footage to be accumulated in a single mission. With these large quantities of data comes the problem of trying to locate video segments of interest amongst the many hours of footage.

1.1 Problem

With the advent and proliferation of inexpensive computer storage mechanisms, storing video footage is only a small problem. A larger challenge is involved in retrieving specific segments of archived footage. Currently, intelligence analysts must painstakingly review video in a serial fashion. Much research is being done, however, to improve the ability to retrieve specific video segments from a larger sequence. The most promising areas are those which are focusing on the semantic content of the video to identify scenes or segments of interest. Unfortunately, the footage being used to further this research often involves segments where visible and distinguishable motion of elements within the video is taking place or where apparent changes in scene content occur. UAV video, on the other hand, most often involves segments where no motion (other than the camera motion itself) or scene content change is taking place. These segments are uninteresting for commercial purposes but may contain targets of high interest to intelligence analysts. To identify and index these segments, other means must be employed and other sources of indexable metadata must be discovered.

1.2 Scope

The key to a robust video retrieval system is in its ability to provide access to specific scenes or segments of interest to the user. The more metadata the user has available to correlate with scene or operational semantics, the more capability they will have for effective ad-hoc querying of the video stream. The commercial market is primarily focusing on the content of the video footage itself to produce indexes for retrieval. This research will focus on supplemental data that complements and further defines the content of the video. Telemetry data gathered during the mission, target lists produced during mission planning, and even solar position information can provide useful clues to both the video content and the potential quality of the images in the video. The quantity of this data, however, can be very large (many millions of bytes). Therefore, it is the intention of this research to identify portions of this information that will offer clues to scene content and flight-pattern semantics that will assist users in locating and accessing video segments of interest. It is proposed that this information, when combined with semantic information gleaned directly from the video footage, will offer a more complete mechanism for scene or segment identification and subsequent retrieval from a video database management system (VDBMS).

1.3 Objectives

This research demonstrates that text-based data accompanying UAV video yields sufficient information to identify and create data items that can be indexed to provide for the identification and retrieval of video segments of interest. Four phases have been identified for accomplishing this goal. Supporting objectives, as well as the phase in which they are completed are provided in the following table.

Table 1 : Research Objectives and Phases

1. Collect and analyze telemetry and target data to identify elements that will yield potentially useful data items and indexes into the video stream.	Phase I
2. Design algorithms for extracting and deriving information from the telemetry stream based on target location and data items identified in Objective 1.	Phase II
3. Design algorithms to calculate the angle and azimuth of the sun to provide clues to potential image quality and offer a more precise querying capability.	Phase II
4. Design and implement a relational database to store data items identified in Objective 1 and solar information in Objective 3.	Phase II
5. Design and implement a user interface to provide querying of data (based upon the data items identified in Objective 1) and retrieval of video segments containing images of targets identified in target lists.	Phase III
6. Design and implement a mission profiler based on telemetry and target data that provides for the retrieval of video segments.	Phase IV

1.4 Assumptions

A few assumptions were made prior to proceeding with this research. Firstly, it has been assumed the information required for investigation would be made available upon request from the sponsor. Sufficient data sets were made available for this research. Secondly, it has been assumed that accompanying the data will be valid definitions that provide insight into the semantic meaning of individual data items. This was available for telemetry data but not for target information. Lastly, it has been assumed the data provided by the sponsor will remain unclassified and be a good representation of actual UAV missions. All video and telemetry data satisfied this assumption.

1.5 Thesis Organization

There are 5 chapters in this document. Chapter 1 introduces the need for random access into UAV video to expedite analysis of the information. Accompanying text-based data is offered as a source for developing indexes into the video stream to expedite identification and retrieval of segments of interest. Chapter 2 offers a brief overview of how UAVs are being employed in military as well as commercial and government sectors. Also covered are unique attributes of national security applications and a model for representing metadata associated with video footage. Chapter 3 outlines the methodology employed by this research to prepare data and identify or calculate the metadata to be associated with the video. A discussion of the requirements for the interface used during the demonstration phase of this research is also provided in Chapter 3. Chapter 4 presents the results of this research and details the interface used to present indexed metadata to the user. This chapter demonstrates that random access into UAV video based on indexed metadata was achieved as proposed. Chapter 5 offers recommendations for future research and offers suggestions as to how recent technological advances and information visualization techniques can enhance the utility of the methodology. Finally, Appendix A contains directions for obtaining copies of the data and software developed during this research.

2 BACKGROUND

Unmanned Aerial Vehicle systems have been in use for tactical reconnaissance since the Vietnam War [CONGR98]; however, broad military and commercial application has taken place only over the past two decades. As a result of their increased use, new methods for storing and exploiting the vast amounts of information being gathered have become desirable. Prior to investigating storage and retrieval issues specifically, a discussion of several uses of UAVs is provided for background. This will provide an understanding of the types and magnitude of data that must be accommodated by visual information retrieval (VIR) systems. This chapter will introduce some of the government, commercial, and military applications of UAVs and how military applications differ from commercial. A brief introduction to VIR systems is included as well as how military content based recognition (CBR) systems must, by nature, differ from commercial. Following the discussion of CBR systems is an introduction to a prototype VIR system in that utilizes the model of information storage and retrieval this research extends. This chapter concludes with an introduction to digital versatile disk (DVD) technology since this technology will be recommended as the future storage mechanism for this research.

2.1 Applications of UAVs

Conventional, manned aircraft are encumbered with several limiting factors associated with cost, design, and safety. The expense of purchasing, maintaining, and flying manned aircraft often make them cost-prohibitive for broad commercial and

military use. Additionally, design limitations (such as fuel capacity) equate to a limited *time-on-target* capability, and, as in the case of military applications, loitering around the target may pose hazardous to both man and machine.

UAVs, however, offer a low-cost, safe alternative to manned vehicles. Government, military, and commercial sectors are exploring and embracing the ever-increasing applications of unmanned aircraft. A few of the applications are discussed below.

2.1.1 Government and Commercial

UAVs are being utilized by government entities such as the Department of Energy (DOE) and the Central Intelligence Agency (CIA). UAVs are also finding application in aerial cropland survey and monitoring forest fires. Likewise, they are being proposed for farming and environmental research and monitoring. More specific details follow.

DOE. The DOE has the responsibility of cleaning and disposing of hazardous contaminants resulting from nuclear materials production [ALBER96]. UAVs are being utilized to assist in the characterization and monitoring of waste sites ranging in size from less than 50 acres to over 10,000 acres [PENDE96] [NYQUI96]. Manned airborne systems have proven cost prohibitive for small sites. Additionally, long lead-times for flight planning make them unsuitable for emergency response scenarios. UAVs offer a cost-effective alternative for surveying small sites (< 50 acres) which comprise most of the sites managed by the DOE. Hobby-class systems fitted with relatively inexpensive photographic equipment are used to supplement or replace manned systems. Figure 1

shows the reduced operating-costs that have motivated the move to small, inexpensive platforms away from larger, more expensive manned ones.

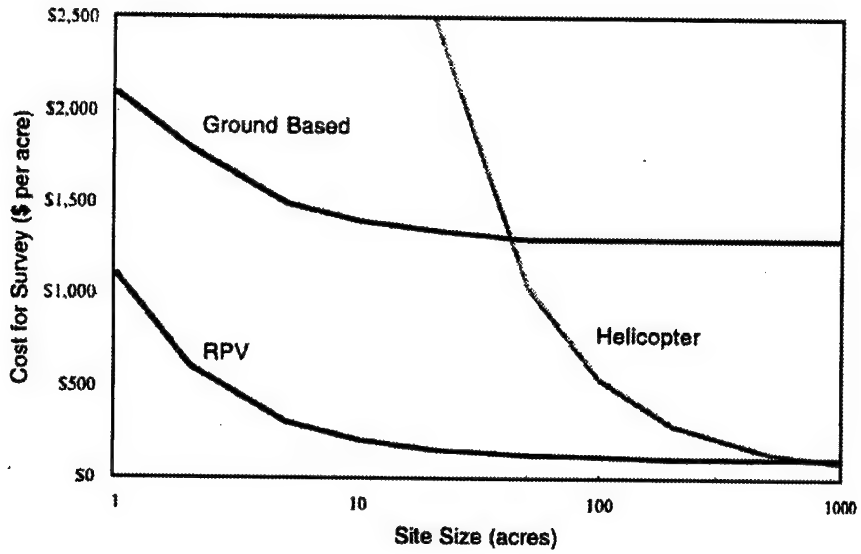


Figure 1: Cost per Acre to Site Size Comparison for Geophysical Surveys [ALBER96]

CIA. The CIA considers the I-Gnat UAV as one of its key intelligence-gathering platforms [VIZAR99]. I-Gnat was used successfully to monitor Serbian troops during the 1999 war in Kosovo. It was also used in 1997 to monitor the terrorist take-over of the Japanese embassy in Peru. Recent upgrades in the onboard Synthetic Aperture Radar (SAR) provide unprecedented image clarity for surveillance and reconnaissance applications.

Other Uses. Commercial applications of UAV technology are many and varied. Companies performing cropland surveys will benefit from the low cost and high-quality images available with low and slow flying unmanned aircraft [HOVER99]. Other farm-related uses being proposed include livestock and crop health monitoring where the costs

or operating environments are not conducive to employing manned aircraft. Possible environmental applications include monitoring of coastal fishing zones, unobtrusive wildlife surveys, volcano monitoring, and tornado spotting and tracking [STILW95].

2.1.2 Military

Military UAV systems are designed to fulfill a broad range of operational reconnaissance and surveillance objectives. Platform categories include short-range (such as Hunter), medium-range endurance (such as Predator), and high-altitude endurance (such as Darkstar). Brief introductions to a few of their many roles are provided below.

Near-Real-Time (NRT) Targeting. UAVs can provide full-time coverage of an area and provide near-real-time intelligence as to target location and behavior.

Battle Damage Assessment. UAVs can locate targets, loiter in the area and provide post-strike assessment. The near immediate feedback assists commanders in determining if a second strike is required on a target.

Special Operations. UAVs can be used to support tracking of high-interest individuals or organizations. Additionally, a UAV's ability to look *over the hill (OTH)* with a downlink to forces in the field can assist safe ingress and egress of forces into hostile territory.

Blockade and Quarantine Enforcement. UAVs provide a cost-effective means to monitor economic, military, and drug-enforcement blockades and quarantines. Enforcement personnel are then free to perform other missions.

Sensitive Reconnaissance Operations (SRO). Missions in this category by nature pose a risk to personnel safety and/or are politically sensitive. UAVs offer a safe, effective means of carrying out these types of missions.

United Nations (UN) Treaty Monitoring. Low operating cost and long time-on-target capabilities make UAVs ideal for monitoring compliance with UN resolutions and treaties. Adherence can be monitored without introducing UN representatives into potentially hostile areas and conditions.

Counter Drug. Endurance UAVs can assist authorities in identifying, tracking, and apprehending trafficking outlaws.

Communications. UAVs have the potential to extend the range of communications systems by acting as a relay. This capability could help bridge the gap between front-line forces and rear-echelon commanders monitoring battlefield progress and performing dynamic mission planning. This capability could also substitute for overwhelmed or damaged satellite links.

Table 2 summarizes the various uses of UAVs within commercial, government, and military communities. This list is not intended to be all-inclusive.

Table 2 : Commercial, Government, and Military Uses of UAVs

Commercial & Government	Military
Characterization & monitoring of waste sites	Near-real-time targeting
Waste site surveys	Battle damage assessment
Surveillance & reconnaissance	Special operations
Monitoring crop & herd health	Blockade & quarantine enforcement
Monitoring coastal fishing zones	Sensitive reconnaissance operations
Wildlife surveys	United Nations treaty monitoring
Monitoring volcanic activity	Counter drug
Storm tracking & monitoring	Communications

2.2 Uniqueness of Military Application

While UAVs are equally adept at supporting military, government, and commercial applications, the *modus operandi* and payload usage often differ in three areas: operational altitude, proximity and angle of approach to the target area, and content and use of payload output. These factors must be considered in the development or acquisition of appropriate video storage and retrieval systems.

The commercial applications described above can be accomplished while operating the platform at any altitude allowed by the terrain and government regulations. Military UAVs, however, are often operated in hostile territory. In these instances, a minimum altitude may be imposed on the platform operator to avoid detection by the enemy. These circumstances may serve to reduce the clarity or detail in the video images being recorded.

Commercial applications are further supported by more freedom in the angle of approach and view of the target area. In many cases, the platform can be flown directly over the target area at low altitudes. A vertical view-angle and low operating ceiling support high quality, highly detailed video and images. For the same reasons discussed in the previous paragraph, military platforms are restricted in many instances to an oblique view of the target at distances of several kilometers. The images and video produced by these less than optimal operating parameters make analysis of the output more difficult.

Finally, commercial applications have different requirements for storing and retrieving payload output. The amount of output (video, imagery, text-based) produced during military operations and the fact that most of the output is archived for post-

mission analysis makes storage and retrieval a prime consideration during selection of an appropriate storage and retrieval system. Most commercial applications, on the other hand, do not approach the quantity of output produced by the military. Additionally, military analysts are often pressed to analyze and produce reports for recently executed missions. This compressed schedule and sense of urgency requires a degree of rapid and precise random access into the video stream not usually required of commercial applications. Table 3 summarizes the difference between the use of UAVs for commercial and military applications.

Table 3: Comparison of Commercial and Military UAV Applications

Commercial	**Military**
Operate at any altitude allowed by the terrain and government regulations allowing low-level passes over the target producing highly detailed video images	Operations over and around hostile territory may impose a minimum operating altitude thus reducing the detail and clarity of video images
Approach the target from any angle allowed by terrain and regulations; can pass directly over the target at low altitudes to obtain the best video images	Hostile operating environments restrict angle of approach and minimum approachable range to the target thus reducing detail and clarity of video images
Lower storage space requirements	High storage space requirement
Less urgency in analyzing output	Rapid processing and analysis of output is required

2.3 Video Information Retrieval Systems

The increased availability and broad use of video information has fueled interest in the area of video information retrieval (VIR). VIR systems seek to retrieve video information based on user-relevant queries. They seek to provide the ability to query and retrieve video information as easily as text-based information.

Accessing information that describes the content of the video is an essential element of VIR systems [DELBI99]. Data that describes the visual elements of the video (such as color, texture, shape, and spatial relationships), editing effects (such as pans, cuts, and camera-angles), and object motion provides indexes for quickly retrieving relevant video segments.

Through surveys of multimedia users, [ROWE94] characterized the types of video queries which should be supported by VIR systems. Based on their findings, they recommend the following indexes to satisfy user queries:

Bibliographic data or *content-independent metadata* includes information about the entire video [DELBI99]. Candidate attributes include *title*, *subject*, *creator*, *date of creation*, etc. The bibliographic elements that could be associated with video used in this research include *platform type*, *mission date*, *mission time*, etc.

Structure data includes attributes that describe the hierarchy of the video. Segment, scene, and shot are terms commonly used to refer to increasingly decomposed elements of the video. The lowest level, the shot, describes the continuous action between the start and stop of camera operation. During the collection of UAV video, the camera operation is continuous. Therefore, segments and scenes are the only levels of decomposition referred to in this research (Figure 2).

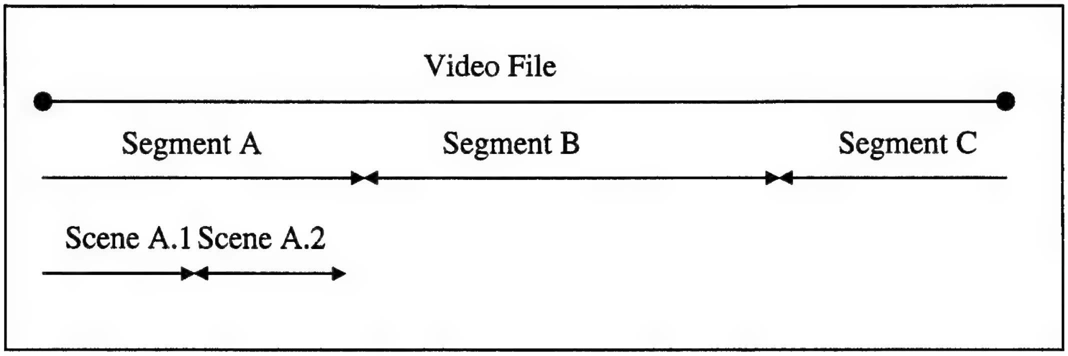


Figure 2: Video Structure

Content data, also referred to as *content-descriptive metadata*, reveals information about the semantic content of the video [DELBI99]. These attributes are reflected by both static elements, such as objects or people, and dynamic elements, such as movement of objects.

Effective video retrieval systems seek to utilize all available information sources, including closed-captioned text, audio, manual annotations, and visual information to build a list of attributes (metadata) describing the video [BOLLE98]. Ideally, video clips should be retrieved from larger sequences based on both temporal structure as well a semantic content. The latter goal, referred to as *content-based retrieval* (CBR), poses the most challenge to VIR developers and is the focus of much research including [GRIFF96], [PEREZ96], [POPE98], [BOLLE98], and [BRONE97]. Approaches range from using visual attributes such as color, shape, and texture, as in the Query By Image Content (QBIC) project [NIBLA93], to indexing associated audio [CHAN96].

Visual information is accessed most effectively when users are given the ability to switch between querying and browsing available information. Browsing offers users a panoramic view of the data and is useful for quickly locating and isolating information of

interest. Integral to effective browsing is the use of effective visualization techniques. Tools should be designed to present visual information to the user in a manner best understood by the user and which summarizes information most effectively. Techniques being explored include mosaics, thumbnail images, and representative points in multi-dimensional space.

2.4 CBR Systems for National Security Applications

Research and development of content based recognition (CBR) systems for commercial applications continue to receive increased attention. However, applications in the national security sector have received less attention according to [BRONE97]. Defense departments, intelligence organizations, and law enforcement agencies are collecting video information at an ever-increasing rate. Due to the different types of data gathered and the varying methods of collection, these organizations require CBR systems with different characteristics than commercial systems. Some of the characteristic differences include [BRONE97]:

Greater variety of media types. Visual (electro-optical) and non-visual (infrared, synthetic aperture radar (SAR), and multispectral) video and images are collected on a regular basis by national security agencies. CBR systems must be able to support the representation of content in both visual and non-visual forms.

Little internal structure. Commercial video applications often employ deliberate use of camera angles, lighting, and motion. These elements provide internal structure that can be exploited by CBR systems to identify probable scene content. A reconnaissance or surveillance video, on the other hand, is free flowing and presents little

or no structure. Additionally, well defined colors, textures, and shapes are a general rule in commercial video. National-security applications, however, have such a broad range of subject matter that these attributes are not useful discriminators for identify the content of a video scene.

Large amounts of metadata. National security applications typically provide much more metadata than is commonly associated with commercial video. Sensor information such as look-angle, field-of-view, and image band as well as precise time and position measurements are commonly associated with this type of video. This metadata should be exploited by CBR systems for this domain because it provides clues to the type and content of the video.

Consideration of multiple data sources. Often, overlapping data sources are available which should be correlated and considered during the query process. Satellite imagery, full-motion video, audio transmissions, environmental data, and intelligence information (Human Intelligence (HUMINT), Signal Intelligence (SIGINT), etc.) combine to provide the composite picture required by analysts of national security data.

Table 4 summarizes the differences between commercial and national security applications. As stated above, these factors must be considered during the development of CBR systems that will be utilized by national security agencies.

Table 4: Differences Between Commercial and National Security Applications

Characteristic	Commercial Systems	National Security Systems
Media Type	visual	visual, non-visual
Degree of Internal Structure of Video Elements	high	low
Amount of Metadata	small	large
Data Sources	few	many

While CBR systems remain a topic of research, the DOD has advanced its efforts to obtain systems that will enhance the ability to retrieve, analyze, and make decisions upon the vast amounts video data available. One such effort has been incorporated in the Multi-Source Integration and Intelligence Analysis (MSIIA) prototype system developed by the MITRE Corporation.

2.5 MSIIA

MSIIA provides a consolidated view of an area of interest by integrating multiple data sources and media types into one system. By integrating multiple sources of information, analysts are able to determine the sensor coverage for a given time and space. One source of information is full-motion video collected by UAV platforms. The methodology used by MITRE to represent metadata associated with video footage is of particular interest and the reason it is presented as background information in this thesis. Brief discussions of the methodology and benefits follow; the reader is directed to [HANSE98] for an in-depth discussion.

2.5.1 Full-Motion Video Track Generation

Support information available from ground stations or on-board systems makes possible the construction of tracks representing the UAV flight path, sensor aim-points, and a general prediction of the field-of-view at any given time (Figure 3). At a minimum the information available includes:

X_v : the longitude of the platform
Y_v : the latitude of the platform
H : the altitude of the platform
X_s: the longitude of the sensor
Y_s: the latitude of the sensor
D_s: the distance from the platform to the sensor aim-point
T : the time the video was captured
W_s: the width of the field-of-view of the sensor

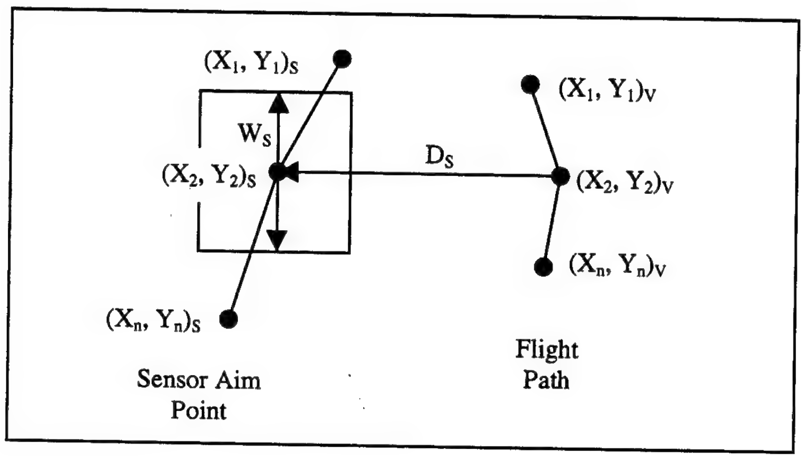


Figure 3: Track Attributes [HANSE98]

Multiple arcs connecting discrete data capture points (or nodes) represent a track. Each node contains the metadata associated with a discrete capture point. Since each node contains a time stamp, it is possible to determine how far into a given track a particular data point lies. This is instrumental in providing random access into the video stream based on space and time. Since the model captures geographic locations at each node, it is possible to fuse target information into video-track information automatically. This is accomplished by retrieving all video tracks encompassing the geographic location of the target. Tags are then placed in the video track identifying the offset location of video containing footage of the target.

2.5.2 Benefits

Storing metadata at nodes and tagging video tracks with target location makes possible the retrieval of video based on content, however limited. Using this model as a basis, this research will extend the ability to retrieve video based not only on the presence of targets but on how the platform and sensors were used while filming the targets as well as calculated solar information. These elements provide the ability to query video content with a higher degree of granularity.

2.6 Digital Versatile Disk

With the massive amounts of text and video data being produced by commercial, government, and military sectors, new and innovative ways are continuously being sought to store this information cheaper, faster, and better. The rapid increase in capacity and reduced price of hard drives has answered the call for stationary storage but portable mediums for transporting large amounts of data remains a problem. The compact disk (CD) made strides in this area by introducing *writable* disks capable of storing up to 640 MB of data. While this may be sufficient for many forms of digital information, it remains inadequate for storing digitized video—less than two hours of digitized video in Motion Picture Expert Group (MPEG)-1 format and less than an hour of MPEG-2 video can be stored on a CD. Recent advances in DVD technology, however, have introduced portable disks capable of storing up to eight hours of MPEG-2 video. These advances will reduce the amount of disks needed to store the mounting quantities of video information becoming available. In the UAV community, this means a single DVD can

hold an entire eight-hour mission reducing the number of storage disks from 6.5 CDs to 1 DVD.

DVD technology is able to deliver much larger storage capacities by advancing CD technology in two key areas. Firstly, as with CDs, data is recorded as a spiral trail of pits. DVDs obtain higher storage capacities by reducing the size of the pits (0.83 μm to 0.4 μm) and the distance between spiral layers (1.6 μm to 0.74 μm).

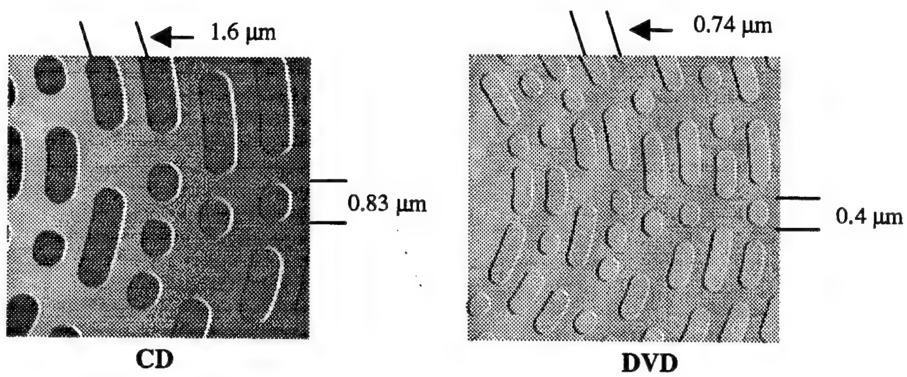


Figure 4: Pit and Spiral Dimensions

Secondly, DVDs are manufactured with either one or two recording surfaces (sides) and either one or two recording layers on each side of the disk. Figure 5 shows a representation of a single sided disk with dual layers. The currently manufactured permutations of DVD configurations are:

Single Sided/Single Layer (SS/SL)
Single Sided/Double Layer (SS/DL)
Double Sided/Single Layer (DS/SL)
Double Sided/Double Layer (DS/DL)

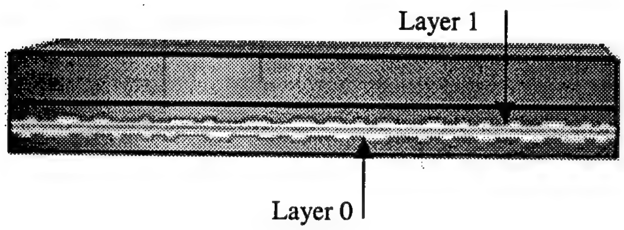


Figure 5: Cross-Sectional View of DVD Showing Two Layers

Multiple recording layers coupled with smaller data pits and tighter spirals give DVDs the tremendous increase over CDs in storage capacity. Table 5 shows how DVD technology has dramatically increased the number of hours of video that can *typically* be recorded on a single disk (actual hours vary with the data rate at which the video was recorded and number of audio tracks).

Table 5: Capacity of Video on DVD and CD [TAYLO98]

Format	Sides/Layers	Hours of Video
DVD	SS/SL	2.2 (MPEG-2)
DVD	SS/DL	4.0 (MPEG-2)
DVD	DS/SL	4.4 (MPEG-2)
DVD	DS/DL	8.0 (MPEG-2)
CD	SS/SL	1.3 (MPEG-1)

3 METHODOLOGY

Much work is being done to investigate methods that allow consumers of UAV video products to graduate from serial search and retrieve methods to random access when attempting to locate a video segment of interest. It is proposed that by evaluating several key sources of mission-related data, methods can be developed to pinpoint information-bearing video segments. The efforts of this research are directed toward using two sources of mission data (telemetry and target information) to pinpoint video segments of interest and allow random access into the data stream. Additionally, solar azimuth and altitude data will be calculated to indicate the position of the sun while the video footage was being recorded. Since image clarity and detail can be greatly enhanced with proper solar illumination, this data will provide indicators of the potential quality of the video images.

Random access into the video stream will be supported by *forward-positioning* data in optimized database tables for rapid location and retrieval of video segments. Additionally, a user interface will provide the capability to profile mission data as well as submit queries to identify and retrieve video segments of interest. This chapter outlines characteristics of the data, the rationale for selecting metadata, preparation and calculations performed on the data, database and interface design, and lastly implementation.

3.1 Data Characteristics

There is an abundance of data associated with each UAV mission. Video, telemetry, target, and environmental data amount to many megabytes to gigabytes of raw data. It is the goal of this research to extract and combine data elements that provide the most information-bearing potential, and use them to assist random access of video segments. The first stage in this process involves understanding the data that is available. An introduction to the telemetry and target information made available for this research is provided in the following paragraphs.

3.1.1 Telemetry Data

Telemetry data records continuous platform and sensor states for the duration for of a single UAV mission. Two sets of data were provided by Air Force Research Laboratory's (AFRL) Signal Data Handling Branch (AFRL/IFEC). One set, the most complete set, comprised data recorded by the Army's Hunter UAV during the All Service Combat Identification Evaluation Team (ASCIET) 1999 field evaluations. Each record in the file contained the telemetry information associated with a single frame in the video. The average file size was 13.3 MB and was provided in an American Standard Code for Information Interchange (ASCII) format text file. For the demonstration phase of this research, data for one mission was selected. This representative sample of data, consisting of approximately 39.7 MB and covering almost five hours, was chosen because it also had accompanying video that would be required in later phases of research. Each record contains 26 fields. The data fields and their meaning are given below.

Table 6: Telemetry Data Fields and Definitions

Clock Time Hours (Hr)	Universal Time Coordinated (UTC) hour of the mission
Clock Time Minute (Min)	UTC minute of the mission
Clock Time Second (Sec)	UTC second of the mission
Camera Center Look Point Latitude (CLat)	Represents the geographic latitude of the center of the frame being recorded by the camera. Values are recorded in decimal-degree format.
Camera Center Look Point Longitude (CLon)	Represents the geographic longitude of the center of the frame being recorded by the camera. Values are recorded in decimal-degree format.
Camera Altitude (CAlt)	Represents the elevation above Mean-Sea-Level (MSL) of the location being recorded. Values are recorded in meters.
Platform Latitude (PLat)	Current geographic latitude of the platform recorded in decimal-degree format.
Platform Longitude (PLon)	Current geographic longitude of the platform recorded in decimal-degree format.
Platform Altitude (PAlt)	Current altitude of the platform measured in meters.
Platform Heading (Heading)	Direction the platform is traveling in relation to North. Values are 0-360 degrees.
Platform Roll (Roll)	Degree of roll the vehicle is experiencing. Positive roll is to the right; negative is to the left.
Platform Pitch (Pitch)	Pitch angle of the vehicle. Positive pitch is up; negative pitch is down.
Bearing	Direction the camera was pointing in relation to vertical axis of the platform. Values range from 0 to 360 degrees.
Camera Depression (CDepr)	The extent to which the camera was pointing down from a horizontal position. 0 degrees is horizontal and 90 degrees is directly below the aircraft.
Zoom Factor (Zoom)	Amount of zoom. Values range from 0 (no zoom) to 15 (full zoom). If the camera lens type (discussed below) is set to *doubled*, these values are considered to be doubled.
Frame Corner Latitude	Geographic latitude (in decimal-degrees) of the recorded frame corner. Four values were included to provide coordinates for all frame corners.
Frame Corner Longitude	Longitude (in decimal-degrees) of the recorded frame corner. Four values were included to provide coordinates for all frame corners.
Camera Lens Type	Identifies whether the lens *doubler* is being used. The *doubler* automatically doubles the zoom factor. A value of 2 signifies the *doubler*; 6 signifies a standard zoom factor.
Camera Mode	Identifies whether IR (value of 1) video is being gathered or not (value of 0).
Polarity	Used when IR video is being gathered. A value of 0 means that black signifies heat and white signifies cold. A value of 1 indicates the opposite effect.

A second set consisted of data captured by Hunter during the Expeditionary Force Experiment (EFX) of 1998. The selected samples from these data sets contained the same data elements as the ASCIET-99 data set except for the last five fields—Frame Corner Latitude, Frame Corner Longitude, Camera Lens Type, Camera Mode, and Polarity. Unlike the ASCIET-99 data set, the EFX-98 data did not contain a record for each frame of recorded video. In some instances, there was as much as 15-20 consecutive seconds of recorded telemetry missing. While not optimal, it was determined the data would still provide enough coverage to meet the objective of the experiment: get the user as close as possible to the video segment of choice using available telemetry information. This data would also demonstrate the ability to accomplish system objectives in the event portions of the recorded telemetry data were corrupted or unrecorded.

Two EFX-98 data files were chosen because they contained the most complete set of data elements for which there was accompanying video. The remaining files only contained time and target latitude and longitude information; these were unsuitable for this research. The files were in ASCII format with an average size of approximately 131.5 KB. They consisted of data from missions with duration of 4-hours and 30-minutes respectively.

3.1.2 Target Data

Target data provides the geographic coordinates of targets projected to be recorded during the mission—basically a flight plan or itinerary. Target data for EFX-98 was provided by AFRL/IFEC in an ASCII format text file. The file contained a target

position number and target latitude and longitude coordinates in degree-minute-decimal seconds (DMS.S) format.

Formal target data for ASCIET-99 was unavailable. To overcome this deficiency, video footage was observed and targets were selected by correlating the time displayed on the video frame to telemetry records for the same mission. The latitude and longitude values recorded in the telemetry file for the correlated time were assigned to the target. Additionally, a representative target designator was assigned. This was not ideal, however, because one objective of this research (Table 1, Objective2) involved using target locations (as recorded in target lists) to identify telemetry records correlating to video footage of the target. Using notional data made this impossible. Final analysis of the results of this research, however, showed that EFX-98 target and telemetry data proved sufficient to demonstrate this objective.

3.2 Metadata Selection

While target and telemetry data serve as information sources in their native formats, they serve more valuably as sources of indexable metadata for randomly accessing video segments of interest. Two approaches were considered in determining the type of metadata to extract or derive from existing target and telemetry data. Metadata can be defined to support a platform-centric or target-centric view of the data. If a platform-centric view is chosen, metadata should be defined which provides insight into how the vehicle was being used during the mission. For example, data items which identify the starting and ending time for a segment where the platform performed a circling pattern, or items identifying when the camera was stationed off the portside of

the aircraft would represent a platform-centric view of the data. A platform-centric approach may prove most applicable in a training context. For example, the data could be used to determine if the platform was navigated correctly during a circling pattern or if the platform was at the correct altitude during the mission. To avoid confusion later, it should be noted that although a platform-centric approach was not used in this research to *identify* metatdata items, the profile tool developed for this research allows a platform-centric *view* of the telemetry and selected metadata. The fundamental difference is that a platform-centric approach to metadata *identification* does not consider information related to what the camera was viewing; a platform-centric *view* of the data merely refers to evaluating what the camera was viewing from the perspective of the platform's location.

For this research, a target-centric approach to metadata identification was chosen rather than a platform-centric approach. Target-centric data items indicate how a specific target was being viewed by the platform. For example, which direction the target was being filmed from, or the zoom factor used during filming are indications of how the target was being viewed. Targets, in this context, represent points or areas of interest. Examples of targets are 1) objects at a particular latitude/longitude, 2) an area between two geographic points, or 3) an area bounded by multiple geographic points. The target-centric approach was chosen because it represents more closely the way the data will be retrieved in an operational context: by areas or objects of interest rather than how the platform was being used. While more target-centric data elements could be chosen, it was determined that the elements described below provide the greatest insight into how the target was being viewed as well as the likely quality of the video footage. The following

paragraphs identify the metadata items derived from telemetry and target data as well as calculated environmental metadata items.

3.2.1 Telemetry

Telemetry data provides insight into the direction the target was being viewed *from*, the zoom factor used, and the distance the platform was from the target. Metadata describing each of these was derived by taking elementary attribute values recorded in the telemetry stream and combining or manipulating them to produce attributes of greater semantic meaning. Specific metadata items identified for this research follow.

Look-Direction. This value is calculated based on the look-direction (CLat, CLon) of the camera and the latitude (PLat) and longitude (PLon) of the platform. This attribute introduces the ability to select video segments based on the direction *from* which the target was being viewed. Values for this data element include eight azimuth regions—N, NE, E, SE, S, SW, W, and NW.

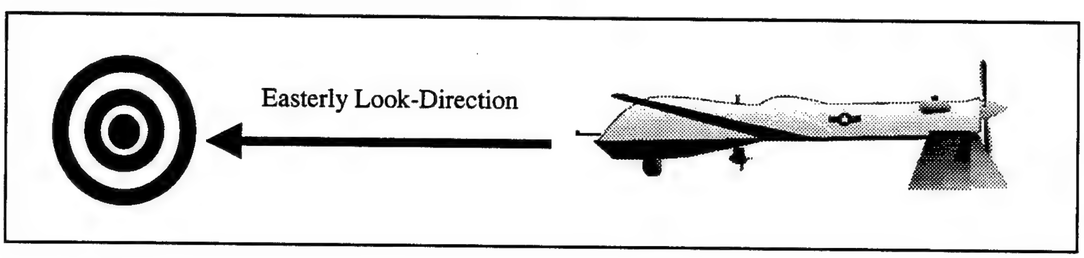


Figure 6: Look-Direction

Zoom. This element provides an indication of the probable level of detail in the image. Four categories of zoom values were defined to reduce the number of entries in the database but still provide sufficient granularity for data retrieval. The categories are:

Table 7: Zoom Categories

Low	recorded zoom values 0 to 3.9
Medium Low	recorded zoom values 4 to 7.9
Medium High	recorded zoom values 8 to 11.9
High	recorded zoom values 12 to 15

Look-Distance. This is a calculated value based on the distance between the camera-center look-point and the platform latitude and longitude accounting for the altitude of the platform. When considered with zoom, this element provides an indication of the probable level of detail in the image.

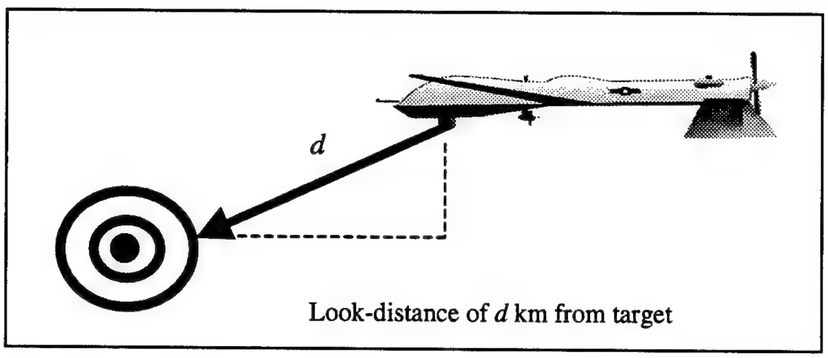


Figure 7: Look-Distance

3.2.2 Target

Target-Designator. The target designator was taken directly from the target list. For this research, notional designators were used. In an operational setting, each target

should be assigned a unique identifier that will serve as the mission-independent target designator.

Latitude and Longitude. These elements were also taken directly from the target list. The fields should be in signed decimal-degree format (e.g. 30.5940, -81.6385). Negative latitudes represent coordinates South of the equator; negative longitudes represent coordinates West of the Prime Meridian.

Target-Name. The target-name was taken from the target list. If a name was not supplied, the target name was documented as *Unknown*.

3.2.3 Environmental

Sun-Angle. Sun-angle is sometimes referred to as *solar elevation angle*. It identifies the angle at which the sun was positioned during a given time and day of the year. The angle is determined by an imaginary line between the target and the sun and the earth's horizon (Figure 8). The value of the angle will be negative for periods during which the sun is below the horizon. This element is calculated based on the latitude and longitude of the camera look-point and the time the image was in view.

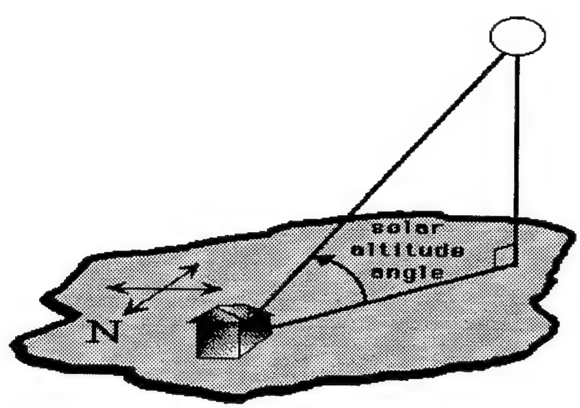


Figure 8 : Solar Altitude Angle [GRONB99]

Sun Azimuth. The solar azimuth angle is the angular distance between due South and the position of the sun at the determined time (Figure 9). Positive values represent positions East of South while negative values represent West of South [GRONB99].

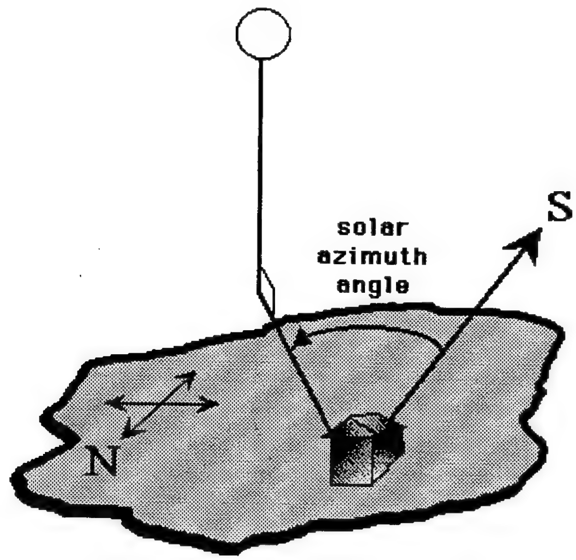


Figure 9 : Solar Azimuth Angle [GRONB99]

Each of the attributes mentioned above were chosen for their potential to provide clues as to the content or quality of video segments. For example, a user may seeks to retrieve video segments which show the greatest amount of detail over the target area. To increase the likelihood of retrieving these segments, they should select images where the sun-direction and look-direction were the same. This would indicate the target was being illuminated on the same side the image was being viewed from thus increasing the potential level of detail that could be expected in the images. By using all elements

cooperatively, users can retrieve images with the highest anticipated image-quality; reducing the search time for the "best" image.

3.2.4 *Other*

Conceptually, UAV video data consists of long segments of recorded images. Each video segment can be further divided into smaller segments containing footage of targets. Finally, each target segment can be further divided into segments delimited by a given action such as a high zoom, an Easterly look-direction, and the direction *from* which the sun was illuminating the target (Figure 10).

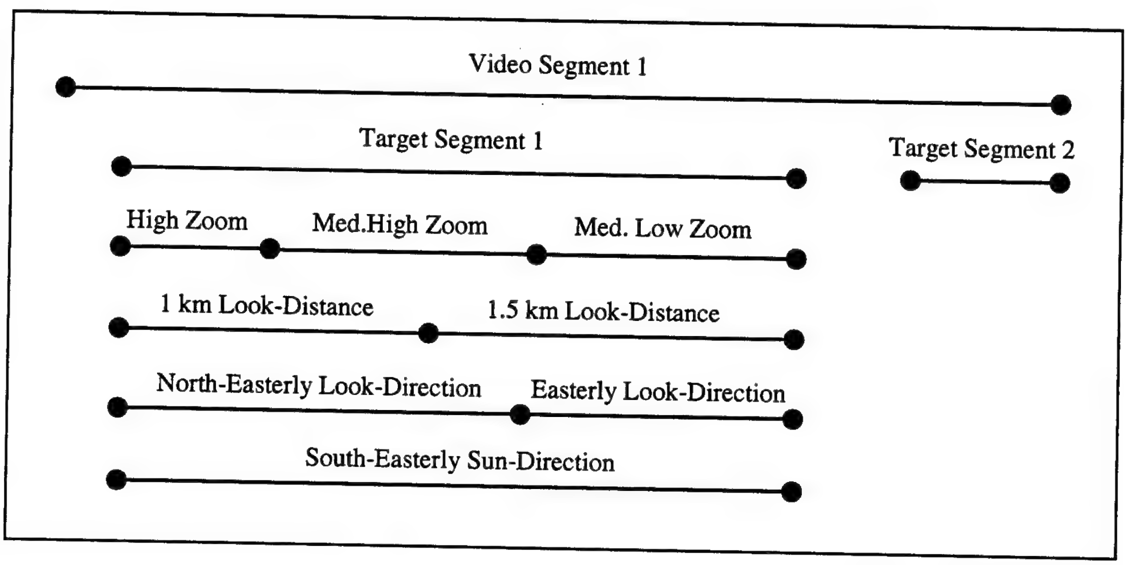


Figure 10: Conceptual View of Video Stream

The following metadata items were selected to identify and delineate the various segments of information.

MissionMonth. The month the mission took place.

MissionDay. The day the mission took place.

VideoSeg. A unique identifier for the video segment. For this research, the file name of the Motion Picture Expert Group (MPEG)-formatted file was used.

The next three attributes take on different meanings based on the context in which they are used. When discussing target segment, look-direction, zoom, or look-distance information, they represent values recorded in the telemetry record. When referring to video data, these attributes represent the displayed time on the video frame. All times are recorded in Universal Time Coordinated (UTC or UT).

StartHr, StartMin, StartSec. These attributes represent the time when, with a high degree of confidence, a particular target is anticipated to be in view of the camera. They are determined by selecting the telemetry record containing the closest latitude and longitude values within a specified distance (discussed in Paragraph 3.4) of a target's latitude and longitude. These attributes are given the hour, minute, and second values recorded in the selected telemetry record. Additionally, these attributes mark the starting time of a video segment.

StopHr, StopMin, StopSec. These attributes mark the stopping time of a recorded segment of video.

3.3 Database Design

The database is implemented as a Microsoft® Access relational database. Access was chosen because it offers the power of a structured query language (SQL) as well as support for the data in its native form--tabular. Additionally, since Microsoft® is prevalent among Department of Defense (DOD) portable platforms, Access offers a maximum level of portability when the system is deployed.

An entity relationship diagram (ERD) is provided in Figure 11 to help the reader conceptualize the relationships that exist between entities (which are later manifested as tables) in the database. Brief discussions of the relationships follow the ERD. Additionally, the ERD identifies the attributes contained within each entity and their data types. If the entity participates as a foreign key in a relationship with another table, the letters FK (foreign key) appear beside the attribute name. Primary keys are made up of all attributes listed in the top portion of each entity. Entities having rounded edges represent dependent entities whose primary key is formed from attributes of one or more other entities. An example of this is the TARGET_SEGMENT entity that takes attributes from both the TELEMETRY entity and the TARGET entity to form its primary key. Square-edged entities represent independent entities—relying on no other entities to form a primary key. The black lines represent relationships between entities. The black dot is placed on the *child* side of the parent-child relationship between entities.

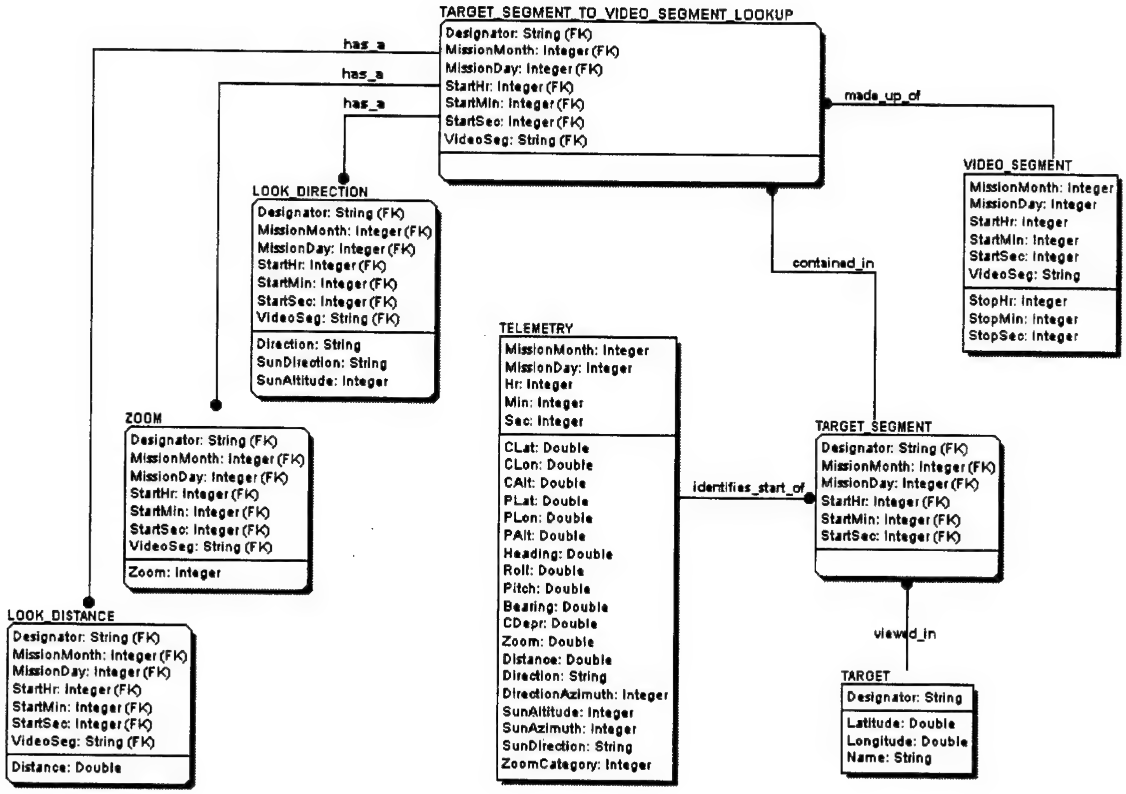


Figure 11: Entity-Relationship Diagram

After the database is implemented, TARGET entries for which there is recorded TELEMETRY will be included in the TARGET_SEGMENT entity (discussed in more detail later). The TARGET_SEGMENT entity participates in a *one-to-many* relationship with the TELEMETRY entity as well as the TARGET entity. More specifically, the start of a target segment is marked by attributes from a single telemetry record while a telemetry record may mark the start of many target segments.

The TARGET_SEGMENT_TO_VIDEO_SEGMENT_LOOKUP entity was created to relate target segments to the video segments that contain them. A target segment may be contained in only one video segment while a video segment may contain

many target segments. Therefore, TARGET_SEGMENT participates in a *one-to-many* relationship with VIDEO_SEGMENT, via the lookup table.

Each TARGET_SEGMENT within a given VIDEO_SEGMENT has related LOOK_DIRECTION, LOOK_DISTANCE and ZOOM values. Each of the former entities participates in a *one-to-one* relationship with TARGET_SEGMENT and a *one-to-many* relationship with VIDEO_SEGMENT via the TARGET_SEGMENT_TO_VIDEO_SEGMENT_LOOKUP entity. While it is possible to have multiple look-directions, look-distances, and zoom values for each target segment, only a single value was assigned to minimize program complexity of the implementation discussed in Chapter 4. It was determined that a single value was sufficient to demonstrate the objectives of this research; Chapter 4 bears this out.

3.4 Data Preparation and Database Population

Target, video, and telemetry files, in their native format, are not sufficient to meet the objectives of this research. During this research, Microsoft®Excel was used as an intermediate format during the processing of target and telemetry files into Microsoft® Access Database tables. The video files must be converted from raw HI-8 video to digitized MPEG files. The following steps identify the actions and algorithms used to convert the data and populate the database. At this point, it is assumed the Access database has been created and all tables have been defined as represented in the ERD.

Step 1: Convert Target File to Excel Spreadsheet and Import into Database

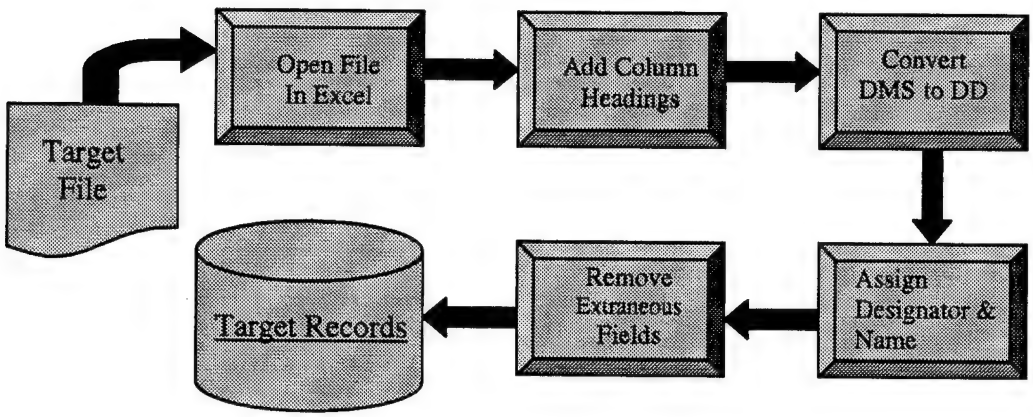


Figure 12: Target File to Target Entity Process Diagram

The target file is converted into a spreadsheet to make it easier to import into the database. If the file is not in a tabular format, the data must be manually entered into the spreadsheet. Once the target file has been opened or a new file has been created in Excel, column headings are added. This ensures that values are assigned to the correct database attributes when the spreadsheet is imported into the database in a later action.

The target latitude and longitude values are checked to ensure they are in decimal-degree format. This is done to ensure uniformity of attribute formats. In some instances, latitudes and longitudes may be documented in other formats (Universal Transverse Mercator (UTM), Degrees-Minutes-Second (DMS)). In these instances, the coordinates must first be converted to decimal-degree format. UTM coordinates may be converted by using a shareware tool such as *Corpscon for Windows* developed by the Army Corps of Engineers [ARMY99]. DMS can be converted to decimal-degrees by using the formula:

$$(((Seconds / 60) + Minutes) / 60) + Degrees$$

Degrees-Decimal Minutes (DM.M) may be converted by using the formula:

$$(\textit{Decimal-Minutes} / 60) + \textit{Degrees}$$

Each target should be assigned a unique identifier. For this research, if an identifier was not provided in the target file, one was assigned. Additionally, each target should have a name. Again, for this research, if one was not provided in the target file, it was assigned the value *Unknown.* For those instances when targets were selected by viewing the video, a notional designator and name was assigned.

The only data items required from the target file are target name, target latitude and longitude, and target designator. All other items should be deleted or omitted from the spreadsheet.

The final action involves importing the spreadsheet into the TARGET table in the database. This is done through the use of an Access macro that simply reads the spreadsheet into the table.

Step 2: Convert Telemetry File to Excel Spreadsheet and Import into Database

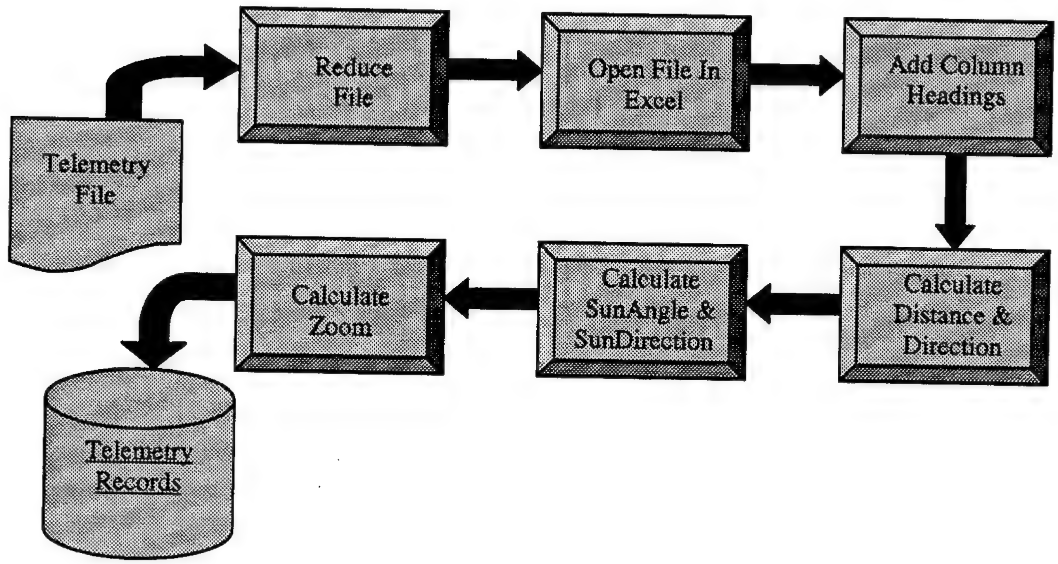


Figure 13: Telemetry File to Telemetry Table Process Diagram

The telemetry file may contain many unnecessary records. One of the files used for this research included multiple records for each second of video while a second file contained only one record every few seconds of video. The former case introduces unnecessary storage and processing overhead. Therefore, an algorithm is necessary to remove all extraneous records before opening the file in Excel (Figure 14). For the purposes of this research, a UNIX® Awk script was created to ensure only one record per recorded second of telemetry remained in the file. The script also appended the MissionMonth and MissionDay attribute values to the data stream.

```
Program ReduceFile(InputFileName As String, MissionMonth As Integer,
                        MissionDay As Integer, OutputFileName as String)

        Open(InputFileName) For Reading
        Open(OutputFileName) For Writing
        Set Old_Time = 99
        While (GetLine(InputFile) != EOF) Do
                While(GetLine.Second = Old_Time) Do
                     If (GetLine(InputFile) = EOF) Then Exit
                End Do
                Set Old_Time = GetLine.Second
                WriteLine(OutputFile, MissionMonth, MissionDay, GetLine)
        End Do
End Program
```

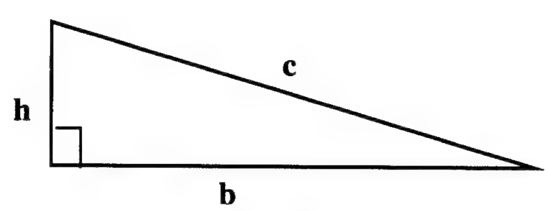
Figure 14: Reduce File Algorithm

As in Step 1, column headings are added to the spreadsheet to assist importing the spreadsheet into the database. This action is followed by the calculation of the distance between the platform and the camera-center look-point (CLat, CLon). A geodesic (Great Circle) distance computation is used to calculate the distance between the camera-center look-point and the coordinates of the vehicle (PLat, PLon). This provides the distance along the surface of the earth but does not consider the altitude of the vehicle. The algorithm (Figure 15) used to compute distance along the surface of the earth was borrowed from [KINDR98] with modifications made to account for the altitude of the platform. The computational formula is based upon the Haversine Formula.

```
longitude_difference[1]  = longitude1[1] - longitude2[1]
latitude_difference[1]  = latitude1[1] - latitude2[1]

temp1 = (Sin(latitude_difference/2)^2 + Cos(CLat[1]) * Cos(PLat[1]) *
          (Sin(longitude_difference/2))^2

temp2 = 2 * Atan2(Sqrt(temp1), Sqrt(1-temp1)) // See Note 2

earth_distance = EARTH_RADIUS * temp2       // EARTH_RADIUS = 6,367,000 meters

distance_in_meters = Sqrt((earth_distance)^2 + (PAlt)^2)

Note 1:  Converted to radians (1 radian = Π/180)
Note 2:  Atan2() calculates Atan() and determines sign of the output based on the sign of the
inputs.
```

Figure 15: Distance Computation Algorithm

The altitude must be considered to obtain the *real distance* between the airborne platform and the observed point. *Real distance* (c) is calculated by using the Pythagorean Theorem (Figure 16) with the distance calculated in Figure 15 (b) and the altitude of the vehicle (h) as recorded in the telemetry record. Although not done for this research, Digital Terrain Elevation Data (DTED) data can be used to provide more accuracy for the altitude of the vehicle given the terrain at the platform coordinates.



$$c^2 = b^2 + h^2$$

Figure 16: Pythagorean Theorem

Although equations exist for calculating exact distances, accounting for the curvature of the earth, between target and platform, their insignificant precision gain does not justify the increased computational and programmatic complexity induced by using them. Figure 17 demonstrates this by showing the insignificant difference in the distance computation using the Pythagorean formula and a formula for calculating the distance between a point on the earth and an object in the sky [PRATT86].

Assume a platform whose coordinates (in degrees), when projected on the surface of the earth, are 30.468N, –86.8609W and a target at coordinates 30.4540N, –86.8670W. The platform is flying at an altitude of 1239.3 meters and the distance between the two coordinates (accounting for the curvature of the earth) is 1661.86 meters.

Pythagorean Formula

a = distance from target to platform
b = altitude of platform = 1239.3 m
c = straight line distance from target to platform coordinates = 1661.86 m

$$a^2 = b^2 + c^2$$
$$= \mathbf{2.07\ km}$$

Earth to Elevated Object Formula

r_e = radius of the earth = 6378 km
r_o = r_e + altitude of the object = 6379.2393 km
L_e = Latitude of point on the earth = 30.4540 degrees
l_e = Longitude of point on the earth = -86.8670 degrees
L_o = Latitude of object = 30.468 degrees
l_o = Longitude of object = -86.8609
d = distance from ground point to platform

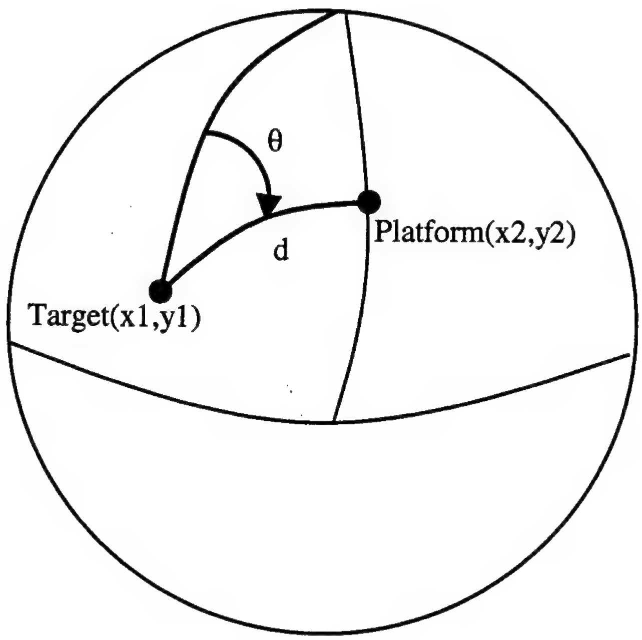
$$\cos(\lambda) = \cos(L_e)\cos(L_o)\cos(l_o - l_e) + \sin(L_e)\sin(L_o)$$

$$d = r_s\sqrt{1 + \left(\frac{r_e}{r_s}\right)^2 - 2\left(\frac{r_e}{r_s}\right)\cos(\lambda)}$$

= **2.09 km** (a delta of 20 meters or about 66 feet)

Figure 17: Comparison of Formulas to Compute Distance

The direction, or heading, *from* the target being observed *to* the platform is calculated by determining the angle (θ) between the longitudinal meridian of the target and the arc formed by intersecting the target and the platform (d). The equation used to determine the angle is given below [CARVE54].



$$\mathbf{Cos}(\theta) = \frac{\mathbf{Sin(x2) - Sin(x1) * Cos(d)}}{\mathbf{Sin(d) * Cos(x1)}}$$

Figure 18: Direction Calculation

Since all input values have been derived during the previous action, the direction is easily derived using the following algorithm borrowed from [KINDR98]:

```
If (Sin(temp2[1]) * Cos(CLat[2]) = 0) Then
        theta = 0                              // Starting from South Pole
End If

If (Sin(temp2) < 0) [3] Then
        theta = 2 * PI – ACos((Sin(PLat[2]) – Sin(CLat) * Cos(temp2)) /
                (Sin(temp2) * Cos(CLat)))
Else
        theta = ACos((Sin(PLat) – Sin(CLat) * Cos(temp2)) /
                (Sin(temp2) * Cos(CLat)))
End If

direction = theta
```

Note 1: From Distance Calculation Algorithm in Figure 15
Note 2: Converted to radians (1 radian = Π/180)
Note 3: Since Westerly Longitudes are given negative values. Otherwise use “>”.

Figure 19: Direction Calculation Algorithm

The next action that is performed during this step is to calculate the solar elevation and azimuth angles for each record in the telemetry spreadsheet. Each record is then updated with the computed values.

To compute the elevation angle, it is necessary to know a) the latitude of the observation point, in this case, the camera-center look-point, b) the declination angle of the sun at the given time, and c) the hour angle at the given time. The reader is referred to [GRONB99] for a layman's discussion of the meaning and derivation of declination angle and hour angle. The elevation angle is calculated according to the following formula:

$$\mathrm{Sin}(A1) = [\ \mathrm{Cos}(L) * \mathrm{Cos}(D) * \mathrm{Cos}(H)\ ] + [\ \mathrm{Sin}(L) * \mathrm{Sin}(D)\ ]$$

Where:

A1 = Elevation Angle

L = Latitude of observation point (CLat)

D = Declination angle of sun

H = Hour angle

Figure 20: Solar Elevation Equation [GRONB99]

Once the elevation angle has been computed, the azimuth angle may be derived and appended to each telemetry record in the spreadsheet. The following formula is used to calculate the values:

$$\mathrm{Cos}(Az) = [\ \mathrm{Sin}(A1) * \mathrm{Sin}(L) - \mathrm{Sin}(D)\ ] / [\ \mathrm{Cos}(A1) * \mathrm{Cos}(L)\ ]$$

Where:

Az = Solar azimuth angle

A1 = Elevation angle

L = Latitude of observation point

D = Declination angle of sun

Figure 21: Solar Azimuth Equation [GRONB99]

Next, zoom values recorded in the telemetry record are evaluated and one of the zoom categories identified in Table 7 is appended to the record. The modified spreadsheet is then imported into the database to populate the TELEMETRY table.

Step 3: Populate TARGET_SEGMENT Table

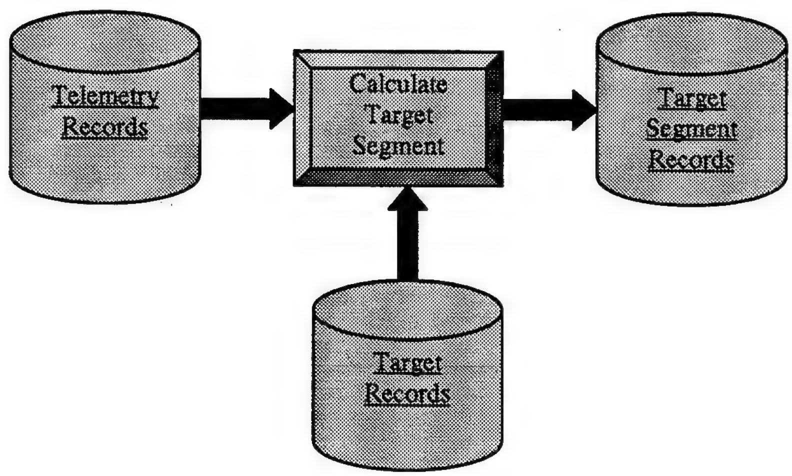


Figure 22: Populate Target Segment Table Process Diagram

This step involves identifying the telemetry records that contain information about video footage recorded over each target in the TARGET table. Telemetry records whose camera coordinates (latitude and longitude) fall within .0003 degrees of the target coordinates (latitude and longitude) are presumed to contain information relating to that target. The threshold of .0003 degrees (about 100 feet at the latitude and longitude of the data provided) was chosen because, through experimentation, it was determined that this was the minimum value that would identify telemetry records for *all* targets provided—

lower values did not return telemetry records for *all* targets. A threshold this small will increase the probability the target was in view during recording since the coordinates of the target will be close to the camera coordinates. It is understood that the threshold may vary depending on the altitude of the platform and the zoom factor and look-angle of the camera. Future research should consider a dynamic calculation of the threshold based on the parameters mentioned above.

Once all records within the threshold are identified, the date and time of the record with the smallest delta from the target position is selected to represent the starting time of the target segment. This information is then recorded in the TARGET_SEGMENT table.

A complete target segment, for the purposes of this research, is designated as 15 seconds prior to the segment start time and 15 seconds following the start time. An arbitrary segment length was selected because at this time it is impossible to determine when the target is no longer in view. This would require knowing the target bounds rather than a single geographic point as is the case with the target data provided.

Step 4: Populate VIDEO_SEGMENT and TargetSeg_To_VideoSeg_Lookup Tables

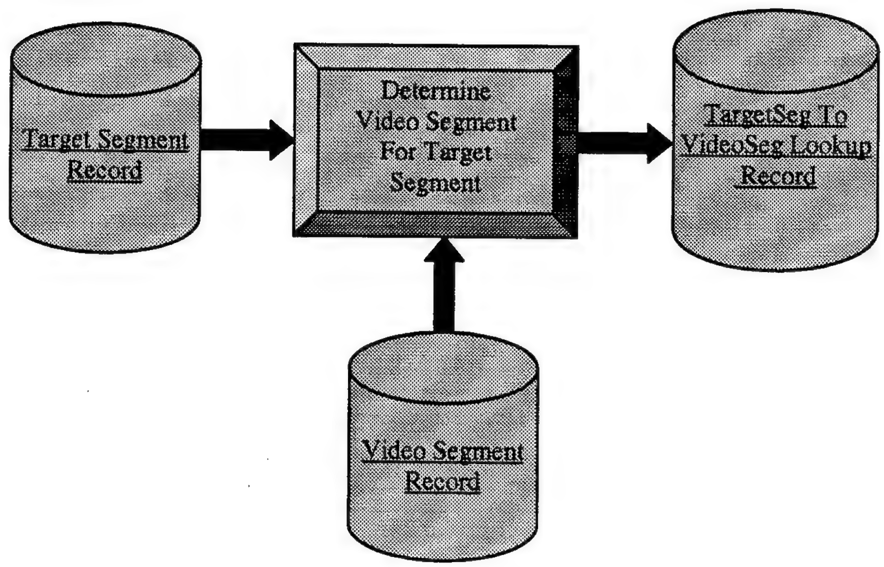


Figure 23: Target and Video Segment to Lookup Table Process Diagram

Video is typically supplied in analog format on Hi-8 (8mm) or VHS tapes. It is necessary to convert the video stream into a digital format since the video viewer used for this research accommodates digitized video only. This can be accomplished by using a software tool such as SNAZZI™ [DAZZL97] or Matrox PC-VCR Remote [MATRO99]. For this research, SNAZZI™ software and hardware at the 88th Communications Group Multimedia Center was used. Video segments of approximately 70 minutes in duration were captured in MPEG-1 format at a rate of 1MB/sec and written to CD-ROM.

It was neither necessary nor practical to digitize all the video footage available for this research. Therefore, the information contained in the TARGET_SEGMENT table was used to ensure, at a minimum, segments containing footage of targets were captured.

Populating the VIDEO_SEGMENT table is done manually. The digitized video file is reviewed to determine the start and stop times recorded on the video frames. The database is manually updated to reflect the segment name as well as start and stop times and date.

The TARGET_SEGMENT and VIDEO_SEGMENT records are used to determine which video segment each target segment resides in. The Structured Query Language (SQL) code in (Figure 24) is used to determine this correlation and store the results in the TargetSeg_To_VideoSeg_Lookup table.

```
INSERT INTO TargetSeg_To_VideoSeg_Lookup
SELECT T.Designator AS Designator, T.MissionMonth AS MissionMonth,
        T.MissionDay AS MissionDay, T.StartHr AS StartHr, T.StartMin AS
        StartMin, T.StartSec AS StartSec, V.VideoSeg AS VideoSeg
FROM TARGET_SEGMENT AS T, VIDEO_SEGMENT AS V
WHERE ( T.MissionMonth = V.MissionMonth
        AND T.MissionDay = V.MissionDay
        AND ((V.StartHr < T.StartHr) OR (V.StartHr = T.StartHr AND
                V.StartMin < T.StartMin) OR (V.StartHr = T.StartHr AND
                V.StartMin = T.Startmin AND V.StartSec <= T.StartSec))
        AND ((V.StopHr > T.StartHr) OR (V.StopHr = T.StartHr AND
                V.StopMin > T.StartMin) OR (V.StopHr = T.StartHr AND
                V.StopMin = T.StartMin and V.StopSec > T.StartSec)))
ORDER BY V.VideoSeg, T.Designator, T.MissionMonth, T.MissionDay,
        T.StartHr, T.StartMin, T.StartSec;
```

Figure 24: SQL to Populate TargetSeg_To_VideoSeg_Lookup Table

Step 5: Populate LOOK_DIRECTION, LOOK_DISTANCE, and ZOOM Tables

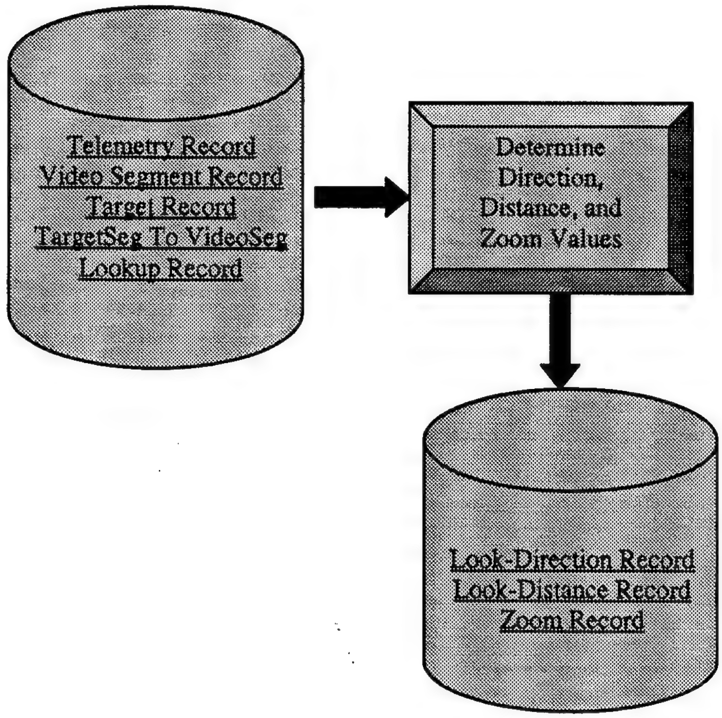


Figure 25: Look-Direction, Look-Distance and Zoom Tables Process Diagram

The TELEMETRY, VIDEO_SEGMENT, TARGET_SEGMENT, and TargetSeg_To_VideoSeg_Lookup tables are used to populate the LOOK_DIRECTION, LOOK_DISTANCE, and ZOOM tables. The TELEMETRY and TARGET_SEGMENT tables are joined on their time attributes (month, day, hour, minute, second) to determine the look-direction and look-distance for each record in the TARGET_SEGMENT table. The LOOK_DIRECTION and LOOK_DISTANCE tables are then populated with their respective values.

For zoom values, the time value associated with each record in the TARGET_SEGMENT table is used to select 30-seconds of recorded telemetry records. Selecting telemetry records having a time value up to 15-seconds before and 15-seconds after the time recorded in the target segment record identifies the 30-second set of telemetry records. The zoom values recorded in these records are averaged to obtain the zoom value for the ZOOM table.

In addition to the look-direction, look-distance, and zoom values, each table is updated with the target segment time (month, day, hour, minute, second) and the video segment in which the target segment can be viewed. A sample query used to populate the LOOK_DIRECTION and LOOK_DISTANCE tables is given in Figure 26; Figure 27 shows the query used to populate the ZOOM table.

```
SELECT T.Designator AS Designator, T.MissionMonth AS MissionMonth, T.MissionDay
        AS MissionDay, T.StartHr AS StartHr, T.StartMin AS StartMin, T.StartSec AS
        StartSec, U.DISTANCE AS Distance, L.VideoSeg AS VideoSeg
FROM TARGET_SEGMENT AS T, TELEMETRY AS U,
        TargetSeg_To_VideoSeg_LookUp AS L, VIDEO_SEGMENT AS V
WHERE ( HR = T.StartHr AND MIN = T.StartMin AND SEC = T.StartSec
        AND MON = T.MissionMonth AND DAY = T.MissionDay
        AND T.Designator = L.Designator
        AND T.MissionMonth = L.MissionMonth
        AND T.MissionDay = L.MissionDay
        AND T.StartHR = L.StartHr
        AND T.StartMin = L.StartMin
        AND T.StartSec = L.StartSec
        AND L.VideoSeg = V.VideoSeg
        AND (((HR*3600)+(MIN*60)+SEC) >=
                ((V.StartHr*3600)+(V.StartMin*60)+V.StartSec))
        AND (((HR*3600)+(MIN*60)+SEC) <=
                ((V.StopHr*3600)+(V.StopMin*60)+V.StopSec)))
ORDER BY T.Designator, T.MissionMonth, T.MissionDay, T.StartHr, T.StartMin,
        T.StartSec, U.Distance, L.VideoSeg;
```

Figure 26: Sample SQL to Populate Look-Direction and Look-Distance Tables

```
INSERT INTO Zoom
SELECT T.Designator AS Designator, T.MissionMonth AS MissionMonth,
        T.MissionDay AS MissionDay, T.StartHr AS StartHr, T.StartMin AS
        StartMin, T.StartSec AS StartSec, AVG(U.ZOOMCATEGORY) AS
        Zoom, L.VideoSeg AS VideoSeg
FROM TARGET_SEGMENT AS T, TELEMETRY AS U,
        TargetSeg_To_VideoSeg_LookUp AS L, VIDEO_SEGMENT AS V
WHERE ( (((HR*3600)+(MIN*60)+SEC) –
                ((T.StartHr*3600)+(T.StartMin*60)+T.StartSec) >= -15)
        AND (((HR*3600)+(MIN*60)+SEC) –
                ((T.StartHr*3600)+(T.StartMin*60)+T.StartSec) <= 15)
        AND MON = T.MissionMonth AND DAY = T.MissionDay
        AND T.Designator = L.Designator
        AND T.MissionMonth = L.MissionMonth
        AND T.MissionDay = L.MissionDay
        AND T.StartHR = L.StartHr
        AND T.StartMin = L.StartMin
        AND T.StartSec = L.StartSec
        AND L.VideoSeg = V.VideoSeg
        AND (((HR*3600)+(MIN*60)+SEC) >=
                ((V.StartHr*3600)+(V.StartMin*60)+V.StartSec))
        AND (((HR*3600)+(MIN*60)+SEC) <=
                ((V.StopHr*3600)+(V.StopMin*60)+V.StopSec)))
GROUP BY T.Designator, T.MissionMonth, T.MissionDay, T.StartHr,
        T.StartMin, T.StartSec, L.VideoSeg;
```

Figure 27: SQL Statement to Populate Zoom Table

A finer level of granularity in recorded values may be obtained by identifying when each of the attributes (look-direction, look-distance, and zoom) changed value rather than taking a single representative value or the average value over the segment. This was not done for this research, however, because the design and coding effort was not justified by the research objectives—locating and retrieving video segments based on attributes of semantic value.

3.5 Interface Design

The interface consists of two parts: a query tool and a profiling tool. The query tool is designed to demonstrate the ability to select video segments based on indexed attributes (metadata) of high semantic meaning. It is target-centric, meaning that all queries are based upon targets identified in the target list.

The profiling tool provides the ability to graphically profile an entire mission. It offers the ability to see the mission from a *birds-eye* view while still providing the capability to observe information about a single point. The profile differs from the query tool in that it is not restricted to retrieving information related to identified targets. Instead, it can be used to retrieve information about locations along the flight-path of the platform that may or may not contain targets. In this respect, it provides access to *every* segment of recorded video rather than just segments containing targets.

This section outlines the requirements against which the query and profile tools are designed and built. Also included is a brief discussion of the language and application programmer interface (API) used to build the tools.

3.5.1 Requirements

The requirements to be observed during design and implementation of the tools are identified below. The State Transition Diagram (STD) for each tool identifies the states the tools must operate in.

The Query Tool Shall:

1. Demonstrate a capability for random access into recorded video segments.

2. Demonstrate a capability to access video segments based on the user-selected parameters of solar direction, look-direction, zoom, look-distance, target designator, and target name.

3. Allow user-selected parameters to be chosen in any order and any combination. The user shall be able to select one or all parameters to specify query retrieval characteristics.

4. Allow a set of values to be selected with respect to solar direction, look-direction, and zoom parameters. For example, solar direction of South **or** Southeast.

5. Allow a range of values to be selected with respect to the look-distance parameter. For example, look-distance between 3 kilometers and 6 kilometers.

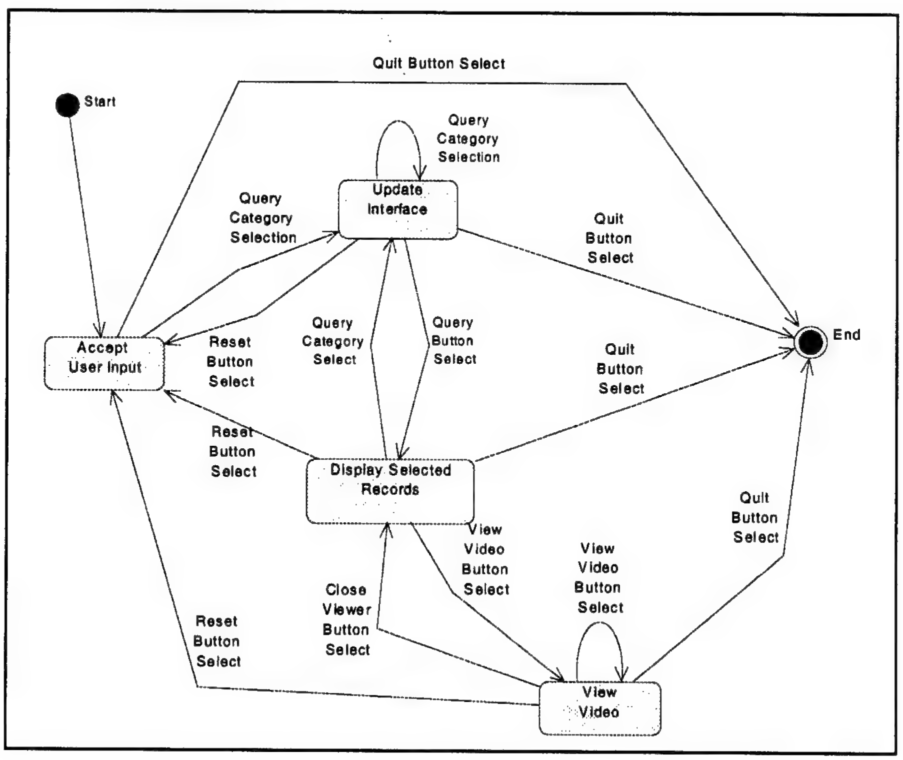


Figure 28: STD for Query Tool

The Profile Tool Shall:

1. Demonstrate a capability to graphically depict contiguous geographic points for which telemetry data was recorded during a single mission.

2. Allow the user to graphically view solar direction, look-direction, zoom, and look-distance values for each point in the profile.

3. Allow the user to select a single point and view the values listed in Number 2 above for the selected point.

4. Allow the use of a bounding box to zoom into an area of interest.

5. Allow the user to view video segments for any single target or set of points displayed in the profile. The duration of video based on selected points will be determined by the time associated with each point in the set. The duration of video for a single target will be 30 seconds (if video exists for that duration).

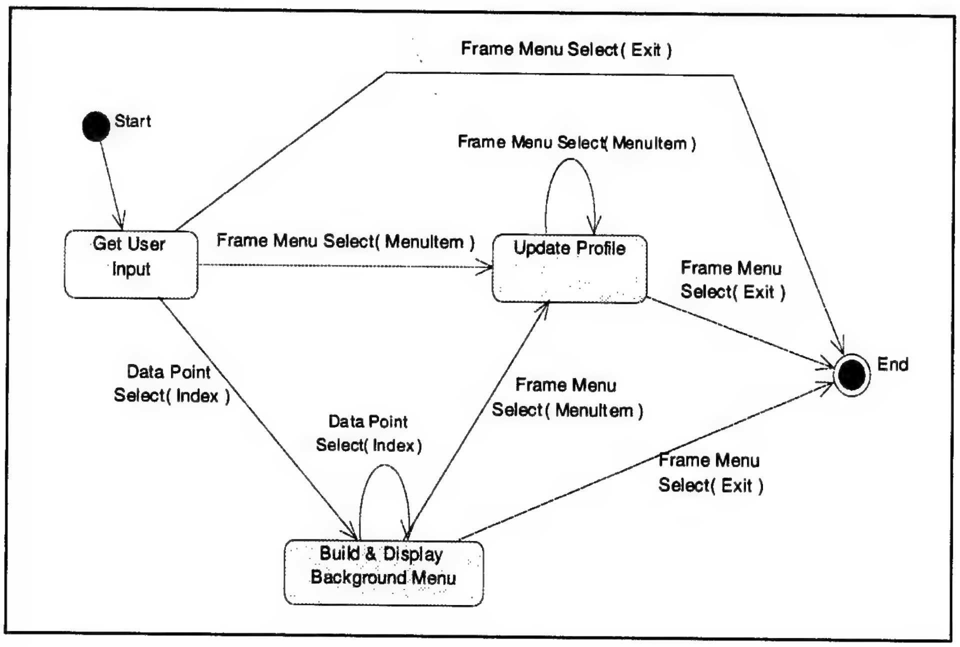


Figure 29: STD for Profile Tool

3.5.2 Implementation

A rapid-prototype approach is used during construction of the query and profile tools. The support application and language chosen should support this methodology. Additionally, the implementation language should be highly portable across hardware platforms. For these reasons, Microsoft Visual Basic, Version 6.0, was chosen. Since Microsoft is the *de facto* standard for DOD Personal Computer (PC) platforms, the tools will meet the objective of being highly portable. Additionally, the Visual Basic language is easily understood and offers the greatest opportunity for easy modification by apprentice or lay programmers. Future releases of the tools can be modified quickly to support changing user requirements.

3.6 Summary

The primary focus of this research is to derive or calculate data items from mission-related telemetry and target data that can be used as indexes to locate and retrieve video segments of interest. The methodology of the research consist of preparing the source data, deriving or calculating metadata items to act as indexes into the video stream, preparing and populating the database, and implementing a query and profile tool to demonstrate results. Chapter 4 includes screen-shots of the interfaces and output from sample queries that demonstrate the methodology discussed in this chapter.

4 RESULTS

This chapter presents results of applying the methodology outlined in Chapter 3 to the telemetry, target, and video data provided by AFRL. It details the steps taken to realize the objectives of this research as outlined in Table 1. The resulting database and software application demonstrate that the telemetry and target data that accompanies a UAV mission, along with calculated solar positions, can be used to provide indexes into video streams thus allowing random access and rapid location and retrieval of video segments. Specifically, this chapter covers the steps taken to prepare the data, the calculation of indexable data values, the construction and population of the database, the graphical user interfaces developed to view and access the data, some minor difficulties encountered while implementing the methodology outlined in Chapter 3, and finally, conclusions.

4.1 Data Preparation

As outlined in Paragraph 3.4, target and telemetry data in their delivered formats were not sufficient to fulfill the objectives of this research. EFX-98 target data was provided in an Excel spreadsheet and a Word document. Target names (if they were available) and target coordinates were extracted from these documents and manually annotated in a new Excel spreadsheet. Target coordinate values were converted from degrees-minutes-seconds format to decimal-degrees format prior to being annotated in the final target spreadsheet. Figure 30 shows sample EFX-98 target information and final

Excel worksheet used in this research. No target lists were available for ASCIET-99 so notional targets were created by viewing the video footage and assigning target coordinates based on the camera-center look-point coordinates in the telemetry record corresponding to the time displayed on the video frame.

Target Spreadsheet

Position	WGS-84 Latitude (N)	WGS-84 Longitude (W)
1	30 33 20.7743	-086 48 48.1874
2	30 31 50.1972	-086 47 57.8093
3	30 30 36.9632	-086 47 51.0497
4	3	

• • •

Range Coordinates

UNCLASSIFIED FOR EFX-98 USE ONLY
EFX-98 EGLIN AFB RANGE SITE COORDINATES

		BE Number	Target AGL
Site 1	303320.9N 0864847.6W Connexes for command building	0467EFX001	158 ft
Site 2	303150.4N 0864758.1W Scud Reload Location	0467EFX002	134 ft

EFX-98 target data is manually annotated in Excel spreadsheet

Designator	Latitude	Longitude	Name
EFXSite1	30.5558	-86.8134	Connexes for command building
EFXSite2	30.5306	-86.7994	Scud Reload Location
EFXSite3	30.5103	-86.7975	V with 16 Hulks

Figure 30: EFX-98 Target Information Flow into Target Spreadsheet

Telemetry data was converted from a flat-file format to an Excel format to make extracting and deriving indexable data items easier. In the case of ASCIET-99 data, extraneous records had to be eliminated with an UNIX® Awk script before the data was imported into Excel. Figure 31 shows the data before and after it was reduced and imported into and Excel spreadsheet as well as the Awk script used to reduce the file.

Flat file containing telemetry records

```
13,59,42,31.9396,-81.8512,16.1,31.9414,-81.8356,
13,59,42,31.9396,-81.8512,16.1,31.9414,-81.8356, • • •
13,59,42,31.9396,-81.8512,16.1,31.9414,-81.8356,
13,59,42,31.9396,-81.8512,16.1,31.9414,-81.8356,
                •
                •
                •
```

input into

Algorithm to remove extraneous

```
{old_time = $3  # initialize
 old_time = 99
 # Get next record
 while ( getline > 0)
 {
      # Skip all frames that have the same time
      # hack as the one just printed to file
      while ( $3 == old_time )
      {if(getline != 1) exit }
      # Got a frame with the next time hack
      # Use the time of the new record as the
      #time to compare subsequent frame
      old_time = $3

      # Print this record
      print ARGV[2] "," ARGV[3] "," $0; temp = 1
  } }
```

Output of algorithm is input into an Excel spreadsheet prior to calculation of additional values (i.e. look-distance, sun-direction, look-direction, etc.)

MON	DAY	HR	MIN	SEC	CLAT	CLON	CALT	PLAT	PLON
3	5	13	59	42	31.9396	-81.8512	16.1	31.9414	-81.8356
3	5	13	59	44	31.9395	-81.8511	16	31.9422	-81.8353
3	5	13	59	47	31.9398	-81.8515	16.6	31.9429	-81.835
3	5	13	59	49	31.9418	-81.8501	12.3	31.9437	-81.8348

• • •

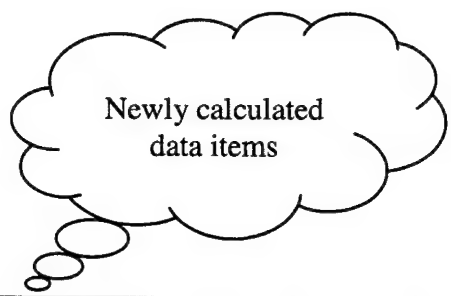
Figure 31: Flow of Telemetry Data from Flat-File to Excel Spreadsheet

4.2 Data Extraction and Derivation Algorithms

To complete the extraction and derivation of indexable data elements, the algorithms discussed in Chapter 3 (Distance, Direction, Solar Elevation, Solar Azimuth, and Zoom Category) were implemented as Excel macros written in Visual Basic. Three macros were developed: one to calculate distance and compass-direction between viewing area and platform, one to calculate sun angle and azimuth, and one to determine a general category (high, medium high, medium low, low) for the zoom factor of the camera. Figure 32 depicts a sampling of telemetry records after the algorithms were executed.

MON	DAY	HR	MIN	SEC	CLAT	CLON
3	5	13	59	42	31.9396	-81.8512
3	5	13	59	44	31.9395	-81.8511
3	5	13	59	47	31.9398	-81.8515
3	5	13	59	49	31.9418	-81.8501
3	5	13	59	51	31.9453	-81.8498

• • •



• • •

ZOOM	DISTANCE	DIRECTION AZIMUTH	DIRECTION	SUN ALTITUDE	SUN AZIMUTH	SUN DIRECTION	ZOOM CATEGORY
1.2	1.5	82	E	26	63	SE	1
1	2	79	E	26	63	SE	1
1	2	78	E	26	63	SE	1
1	1.5	82	E	26	63	SE	1
1.6	1.5	94	E	26	63	SE	1

Figure 32: Telemetry Spreadsheet with New Data Elements

4.3 Database Creation and Table Population

The database was implemented in Microsoft® Access according to the ERD described in Chapter 3. The database consists of eight tables, three queries, five macros, and two modules (Figure 33). The queries, macros, and modules were developed to assist in populating the tables and are described below.

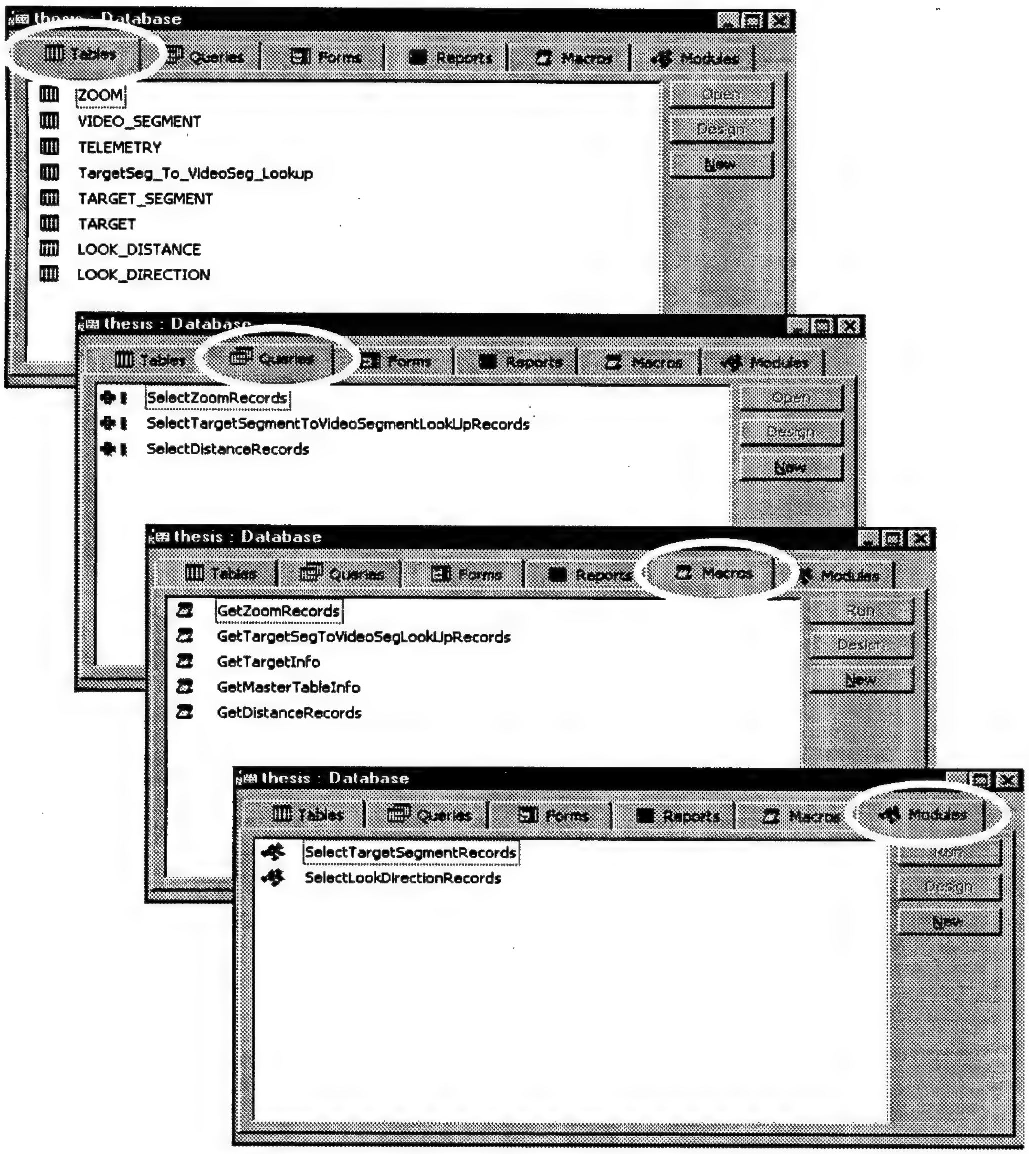


Figure 33: Database Tables, Queries, Macros, and Modules

4.3.1 Queries

The following table describes the SQL queries that were developed to populate the zoom, target segment to video segment lookup, and look-distance tables.

Table 8 : Database Queries

SelectZoomRecords	Selects the average zoom-category value from the telemetry records that correspond to each target segment recorded in the TARGET_SEGMENT table. The query also populates the ZOOM table with the mission month, mission day, start time (hour, minute, second) of the related target segment, name of the video file containing the target segment, target designator, and the average zoom-category value.
SelectTargetSeg_To_ VideoSeg_LookUpRecords	Populates the TargetSeg_To_VideoSeg_LookUp table with attributes identifying the name of the video file each target segment can be viewed from. The table is updated with mission month, mission day, start time (hour, minute, second) of the target segment, name of the video file containing the target segment, and the target designator
SelectDistanceRecords	Selects the look-distance from the telemetry record associated with each target for which there is a TARGET_SEGMENT record identified. The time recorded in the TARGET_SEGMENT table is used to select the telemetry record containing the distance value. The LOOK_DISTANCE table is updated with the target designator, mission month, mission day, start time (hour, minute, second) of the target segment, name of the video file containing the target segment, and the distance between the platform and target.

4.3.2 Macros

Macros were utilized for two purposes: to import data from Excel spreadsheets directly into database tables and rebuild tables when new telemetry records were added to

the TELEMETRY table. The decision was made to delete existing records prior to updating zoom, target segment to video segment lookup, and look-distance tables to eliminate the need for complex SQL or additional Visual Basic code. Otherwise, the existence of duplicate records would have to be verified programmatically. Given the relatively small size of the database used in this research, deleting existing records prior to rebuilding tables did not introduce unacceptable delays in preparing the database. However, as the amount of telemetry data increases, a more appropriate methodology should be implemented to avoid unacceptable processing delays. Table 9 contains descriptions of the macros used in this research.

Table 9: Database Macros

GetZoomRecords	Deletes existing records from the ZOOM table and executes the SelectZoomRecords query
GetTargetSeg_To_ VideoSeg_LookUpRecords	Deletes existing records from the TargetSeg_To_VideoSeg_LookUp table and executes the SelectTargetSeg_To_VideoSeg_LookUpRecords query.
GetTargetInfo	Imports the Excel spreadsheet containing the target information discussed in Paragraph 4.1 into the TARGET table.
GetMasterTableInfo	Imports the Excel spreadsheet containing telemetry records into the TELEMETRY table.
GetDistanceRecords	Deletes existing records from the LOOK_DISTANCE table and executes the SelectDistanceRecords query.

4.3.3 Modules

Visual Basic software modules were used when a single SQL query was inadequate to capture the appropriate information and populate the database. These circumstances were typified by a need to make a decision or transform the data into

another format prior to placing the data into a database table. The modules created for this research are given in the following table.

Table 10: Database Modules

SelectTargetSegmentRecords	Selects telemetry records having camera-center look-point coordinates within a specified distance (0.0003 degrees for this research) of the target coordinates. The recorded time from the closest telemetry record is selected as the median time for the target segment (the entire segment will consist of 15-seconds of video before and after the median time). The TARGET_SEGMENT table is populated with the target designator, mission month and day, and the selected time (hour, minute, second).
SelectLookDirectionRecords	Selects the look-direction from the telemetry record whose time matches the target-segment median time as recorded in the TARGET_SEGMENT table. The look-direction is converted from a numeric azimuth value (0 to 360) to an 8-point compass direction (N, NE, E, SE, S, SW, W, and NW). The LOOK_DIRECTION table is updated with mission month and day, start time (hour, minute, second) of the target segment, name of the video file containing the target segment, target designator, look-direction, and the sun direction (azimuth) and altitude associated with the target segment.

4.4 Target-Centric Query Tool

An interface was developed to allow random access into archived video streams based on user-selected image characteristics including target name and designation, camera zoom level, look-distance between target and platform, direction the target was being viewed *from*, and the direction *from* which the sun was illuminating the target. The following paragraphs discuss how each of these characteristics are used to retrieve

interesting target segments as well as how this information may support mission objectives.

4.4.1 Target Look-Direction

The target look-direction characteristic provides a further refinement in the specification of video segments to be retrieved by the query tool. Eight compass directions (N, NE, E, SE, S, SW, W, NW) are available to specify the look-direction (direction *from* which the target was being viewed) that should be reflected in the retrieved images. Figure 34 depicts a target that was being viewed *from* the West meaning the platform was to the West of the target at the time the video segment was recorded.

Mission Impact: This attribute is useful when a specific view of a target is needed. For example, if it is known that a tank is located on the North side of a building, then video segments depicting a Northerly look-direction will be sought. This attribute allows the presence or absence of these video segments to be quickly ascertained, and if they do exist, to quickly locate and retrieve them for viewing. Currently, without reviewing the telemetry record corresponding to the video image, there is no way to determine the direction *from* which the target is being viewed. Direction can only be calculated using the geographic coordinates of the target and the platform. Without pre-calculated direction information, it becomes necessary to review all footage containing the target in hopes of finding the sought images.

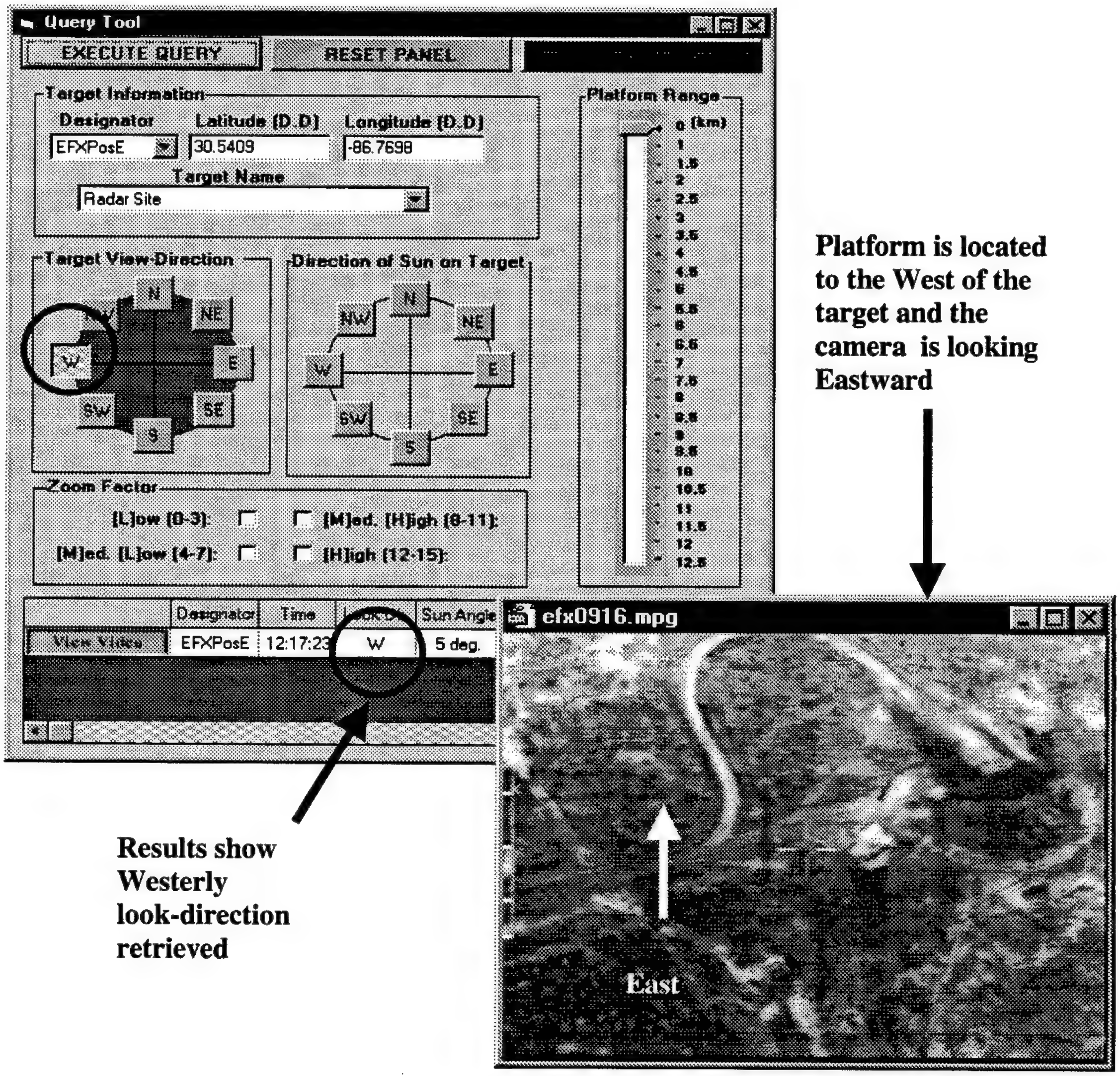


Figure 34: Query Results and Video Image Showing a Westerly Look-Direction

4.4.2 *Solar Illumination Factor*

The query tool can also be used to select video segments depicting a target being illuminated by the sun from a particular direction. While all targets have a calculated illumination direction, this attribute is only useful to describe targets recorded during daylight missions. Night missions are differentiated from daytime missions by either the mission time or the value calculated for the sun's altitude angle at the specified time. Sun angles of less than zero denote night missions. By observing the sun's altitude angle, the user can determine if the records returned by the query correspond to daylight or night mission.

Mission Impact: When combined with look-direction, this attribute can be used to select video segments that offer the greatest degree of target detail. For example, when the sun is illuminating the target from the same direction, or aft of the platform, (e.g. Easterly or Southeasterly look-direction and Easterly sun-direction) shadow obscuring of the target is minimized. Additionally, although not done in this research, the sun's altitude angle, as recorded in the query results, provides a basis for computing the length of the shadow that can be expected around target. Figure 35 shows query results and retrieved video images of a target being viewed from the South while the sun was illuminating the target from the East. By observing the image, it is clear that the shadows produced by the entities in the scene did not obscure the target thus producing a high quality image. Figure 36 shows the types of images that can be avoided by using sun-direction and look-direction characteristics. The image on the left shows a target obscured by shadows as a result of the look-direction be nearly opposite of sun-direction. The image on the right shows a target obscured by sun-glare for the same reason.

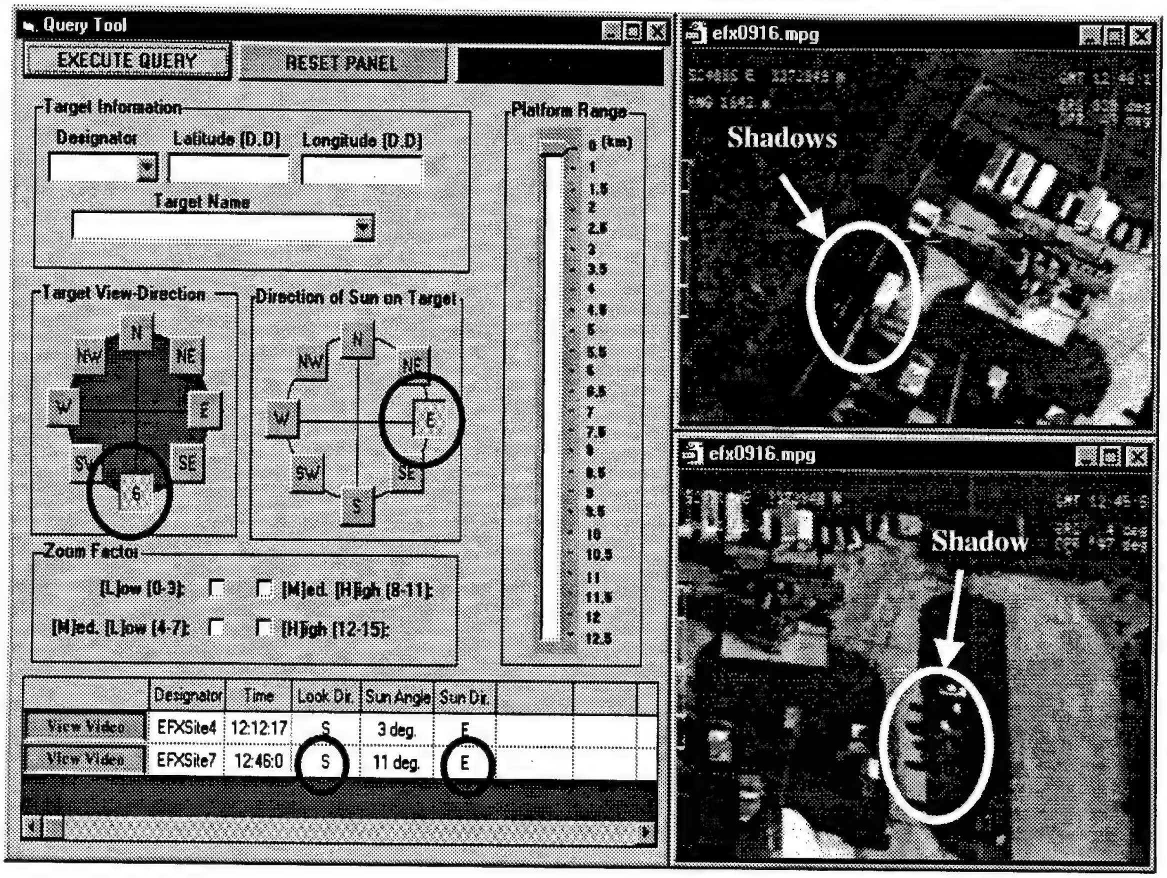


Figure 35: Query Results and Images of a Southerly Look and Easterly Sun

Figure 36: Video Images Obscured by Shadowing and Sun Glare

4.4.3 *Zooms*

The zoom image characteristic can be used to further refine the specification of video segments to images where the zoom-category ranged from low zoom factors (actual zoom factors between 0 and 3) and high zoom factors (actual zoom factors between 12 and 15). Figure 37 shows the query results and a retrieved video image of a query to view all target segments depicting high zoom images.

Mission Impacts: Selecting video segments where a high zoom was used will reveal the greatest amount of target detail in the corresponding video images thus enabling more precise identification of target characteristics.

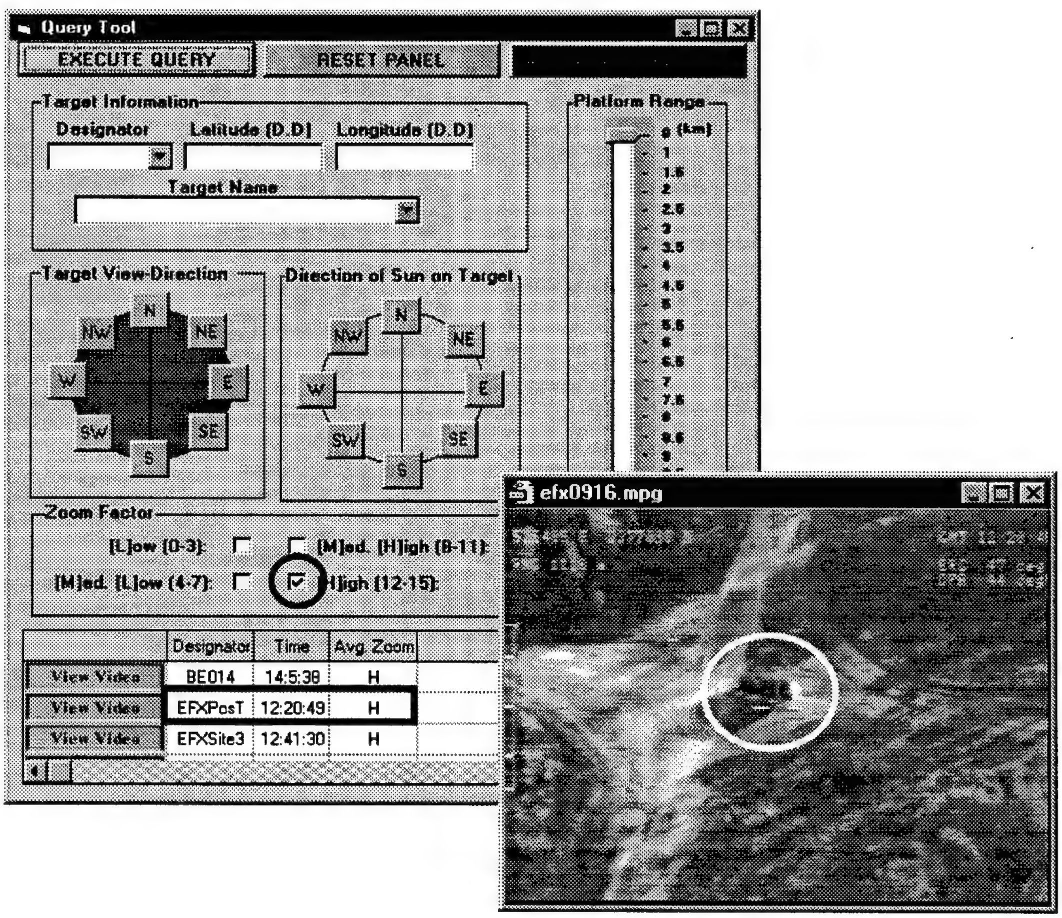


Figure 37: Query Results and Video Image of High Zoom

4.4.4 *Look-Distance*

The look-distance characteristic in the query tool can be used to further refine the selection of video segments to those that were recorded when the platform was within a specified range of the target. The range starts at zero and extends to the maximum distance (measured in kilometers) selected by the user. Targets that have an associated look-distance of less than or equal to the maximum distance will be retrieved.

Mission Impact: As with the other characteristics mentioned previously, look-distance is designed to give the user the ability to retrieve the sharpest, most detailed images available for analysis purposes. Figure 38 reveals how target-detail is affected by distance even at the highest zoom factor. The image on the left was recorded at a distance of 1 kilometer; the image on the right was recorded at a distance of 5 kilometers. It becomes obvious that video images depicting short look-distances and high zooms produce the greatest image detail.

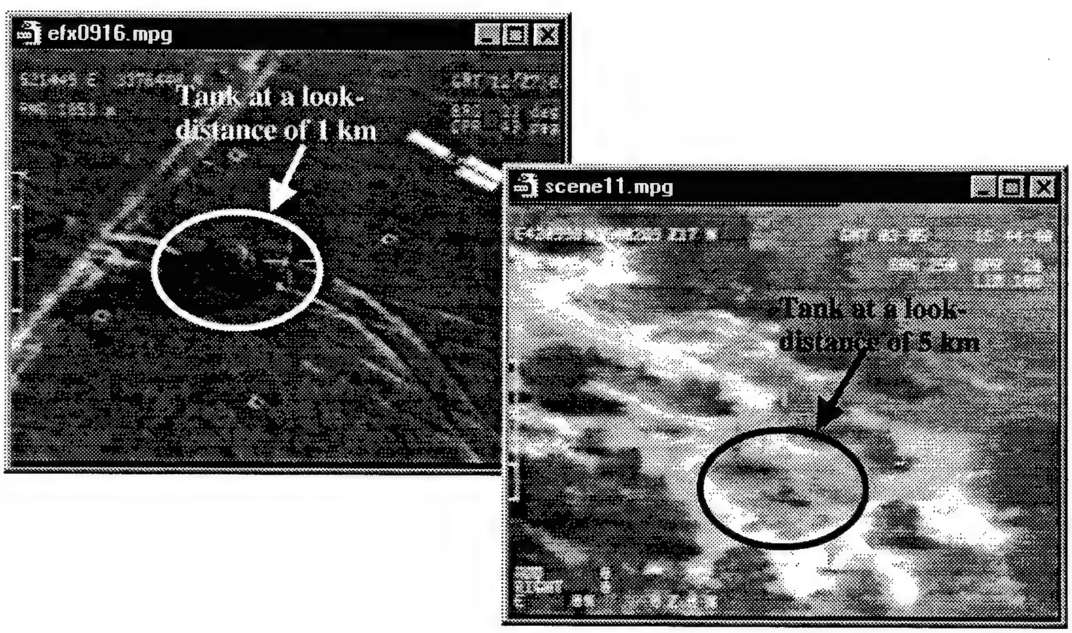


Figure 38: Comparison of Different Look-Distances at High Camera Zoom

4.5 Profile Tool

Whereas the target-centric query tool provides the ability to retrieve video segments containing images of specific targets, the profile tool provides a graphically represented *birds-eye* view of the entire mission. Each of the characteristics described in Section 4.4 are represented graphically in the profile tool to quickly display information about how the platform and camera were maneuvered throughout the mission. Additionally, with the profile tool, users can retrieve any segment of video recorded along the flight path of the platform rather than just video segments containing targets as with the query tool.

Profiling mission data will prove useful in both training and operational environments. In a training environment, a profile provides instructors or evaluators a mechanism for assessing whether the platform and camera were used appropriately to maximize target coverage and image quality. Operationally, the graphical representation of image characteristics provides *at-a-glance* indication of image characteristics (e.g. zoom, look-direction, look-distance, and solar illumination direction). This will allow rapid assessment of where target or area coverage may have been inadequate and thus require a *second look.*

The profile tool builds the displayed image by selecting one telemetry record representing each minute of recorded data. Sampling at this interval depicts ample information to determine general platform and camera usage. Sampling at a higher rate has been shown to produce more data points than is necessary and causes the viewing area to appear cluttered.

Each data point depicted in the profile is actually a complex Active-X control containing multiple pieces of information pertaining to that particular data point. This information includes the data point's latitude and longitude, the time the data point was recorded, and a value for each of the characteristics that can be viewed graphically (zoom, look-distance, look-direction, sun-direction). Storing the information at the data point eliminates the need to query the database prior to displaying graphical information.

The data used to build the profile can be viewed from a platform-centric view or a camera-centric view. The following table describes how the data in the viewing window is to be interpreted for each view.

Table 11 : Data point Meaning by View

Platform-Centric View	Data points represent the location of the platform at the given time. This allows the user to see, from the perspective of the platform, how the target area was viewed.
Camera-Centric View	Data points represent the camera-center look-point at the given time. This view represents *what* the camera was looking at and the configuration of the camera at the time of viewing.

The following paragraphs demonstrate how the profile tool is used to represent video image characteristics. Each description is followed by a discussion of how the information can be used to support military objectives.

4.5.1 Zooms

The profile tool can be used to view the zoom level of the camera for displayed data points. Figure 39 shows a screen shot of the profile tool indicating points where

high zooms were recorded. These points are highlighted by changing the color of the data point to red.

Mission Impact: Since high zooms produce video images with the greatest amount of detail, these segments will be most often retrieved. Therefore, the ability to rapidly locate and retrieve these segments is paramount. Areas in the profile depicting prolonged high zoom levels may indicate an area of interest which requires a closer look by analysts even when a documented target may not exist for that location. These situations may arise when an object of interest is observed while the platform is in transit between targets identified on the flight plan. Post analysis of these images may result in new targets being identified. In a training scenario, this graphic can be used to determine if the correct zoom factor was used for the location and objective in question.

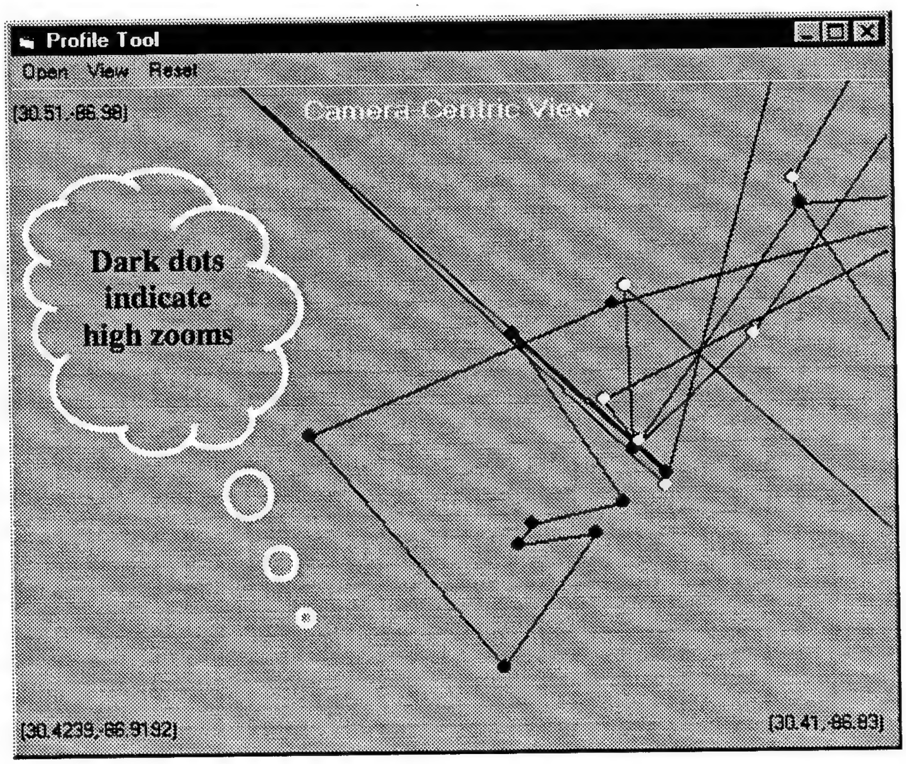


Figure 39: Camera-centric Data Points Where High Zoom was used

4.5.2 Targets

Each target documented in the database can be displayed in the profile by its geographic coordinates. This includes targets for which a target segment was identified as well as those that did not match the criteria for identification of a target segment. As a reminder, target segments were only designated for those targets whose coordinates fell within .0003 degrees of the camera-center look-point coordinates of existing telemetry records. For a discussion of why this threshold was chosen, see Paragraph 3.4, Step 3. Experimentation revealed the .0003-degree threshold to be a good choice for the EFX-98 telemetry and video used in this research. This was evidenced by the fact that all targets identified in the mission activity log that corresponded to the telemetry and video data used in this research were identified and retrieved.

Mission Impact: Plotting known targets and data points allows rapid location and retrieval of video segments containing footage of targets. Two possible scenarios exist for determining when a target may be included in a video segment. Firstly, if the target is the primary focus of the video segment, the target coordinates will fall within a determined radius of the camera-center look-point coordinates. The target-centric query tool capitalized on this fact to retrieve video segments containing the target. Secondly, video footage may exist for which the target was displayed incidentally—meaning it was not the primary focus of the segment and was not within the determined radius of the camera-center look-point coordinates. These portions of video may still prove useful during analysis and should be made available. The profile tool supports both scenarios equally well.

By plotting data points in a camera-centric view and noting the distance between targets and surrounding points, all video that *may* contain footage of the target can be retrieved. Data points falling close to target indicators typically indicate instances where the target was the primary focus of the video. Those further away correspond to instances where the target may appear incidentally in the video footage. Figure 40 depicts a camera-centric view of data points and an associated image revealing a target that was recorded incidentally. It was determined to be incidental to the segment because the camera only panned across the target area without focusing on the target.

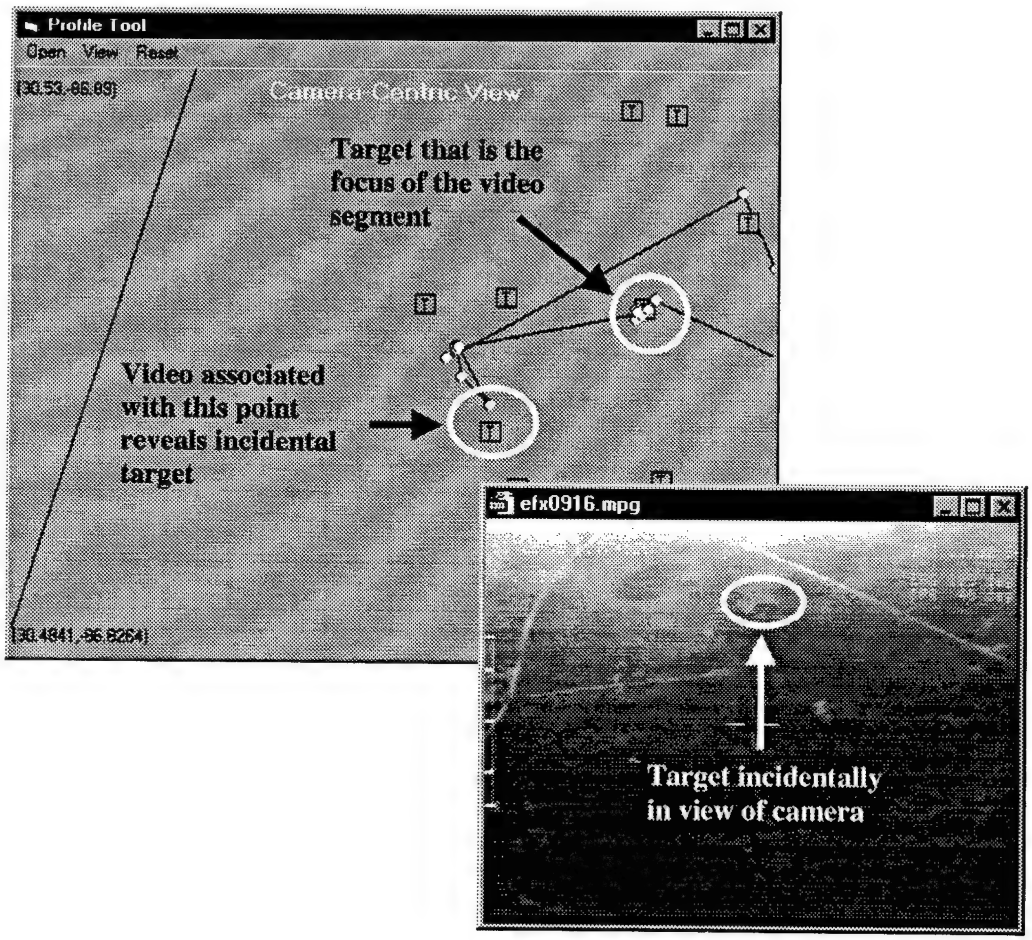


Figure 40: Image Showing Target Recorded Incidentally

4.5.3 Look-Direction and Solar Illumination Direction

The look-direction and solar illumination direction are graphically represented in the profile by colored lines corresponding to four possible compass directions-N, E, S, W. The look-direction line is colored blue to distinguish it from the yellow sun-direction line.

Mission Impact: Like the same characteristics described for the target-centric query tool (Paragraph 4.4.1 and Paragraph 4.4.2), these attributes are used together to select video segments with the highest image detail and clarity. They can also be used to quickly identify if the correct aerial approach was taken to the target area to produce the necessary images. For example, if it is necessary to see images of a target as viewed from an Easterly direction, a camera-centric view of the data, with accompanying target points plotted, will quickly reveal if the images are available. Figure 41 shows the type of plot that reveals the characteristics just mentioned and an image from the retrieved target video.

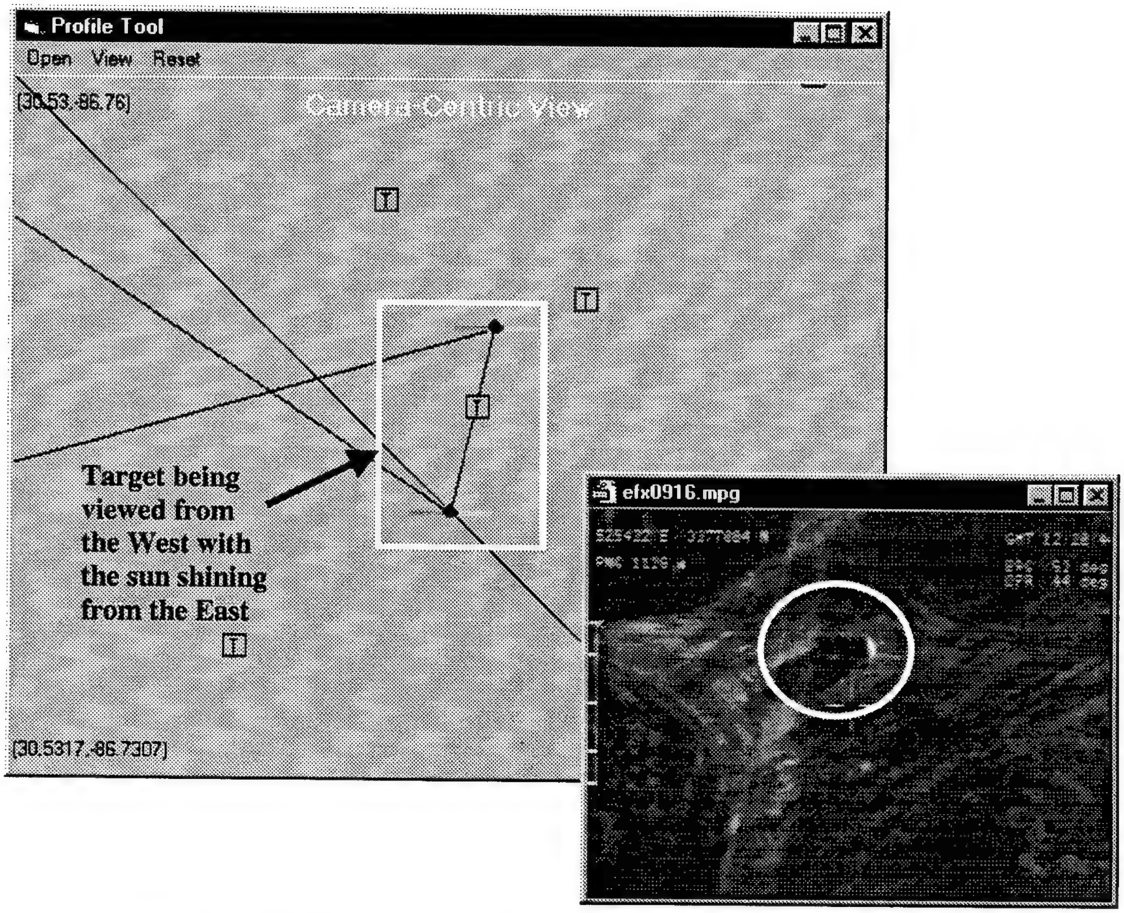


Figure 41: Look-Direction and Solar Illumination Direction Example

4.5.4 Look-Distance

Look-distance is represented graphically by colored circles displayed under the data point. Small red circles represent a close look-distance (0 to 2 km), a slightly larger orange circle represents medium look-distances (2 to 4 km), and long look distances (greater than 4 km) are represented by large white circles.

Mission Impact: The look-distance is useful in at least two ways. As stated in the discussion of look-distance as used with the target-centric query tool (Paragraph 4.4.4), this attribute is an indicator of the likely image detail—close distances produce the

greatest amount of detail. However, this characteristic will also prove useful in post-mission analysis of platform use. Instances where the platform was taken too close to a *hot* target will be readily apparent in the profile.

Figure 42 shows data points with look-distance indicators revealed. All three look-distance graphics are depicted.

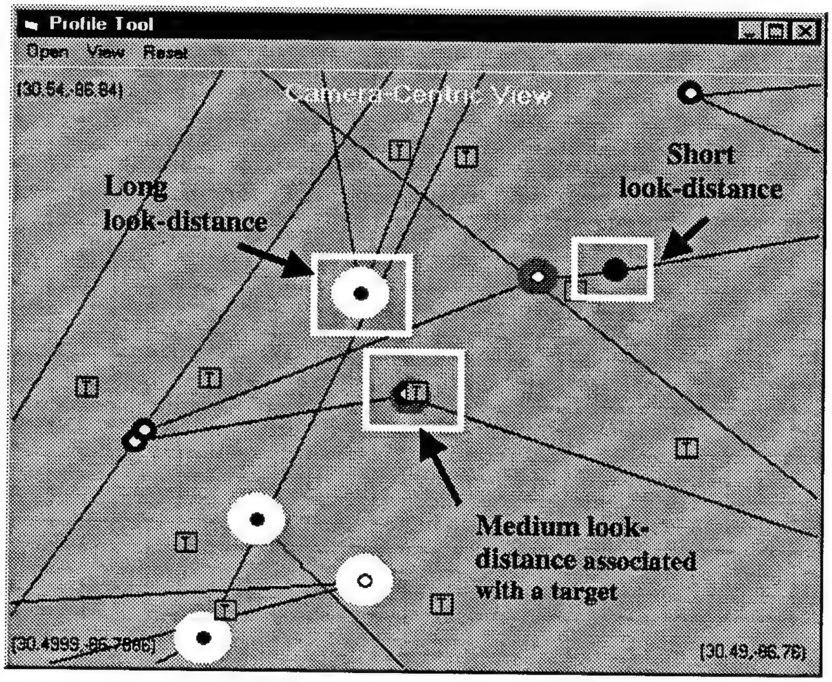


Figure 42: Long, Medium, and Short Look-Distance Graphics

4.5.5 Look-Path

Look-path is the line-of-sight path between the camera-center look-point coordinates and the platform coordinates. This feature provides a more precise representation of the actual look-direction and look-distance between camera and platform.

Mission Impact: Displaying look-paths provides an exact representation of the look-direction and look-distance whose benefits were described in Paragraph 4.5.3 and Paragraph 4.5.4. Figure 43 shows a look-path for a single data point. The data-point represents the camera-center look-point coordinates being viewed *from* a Westerly direction at a medium distance (2-4 km) from the platform.

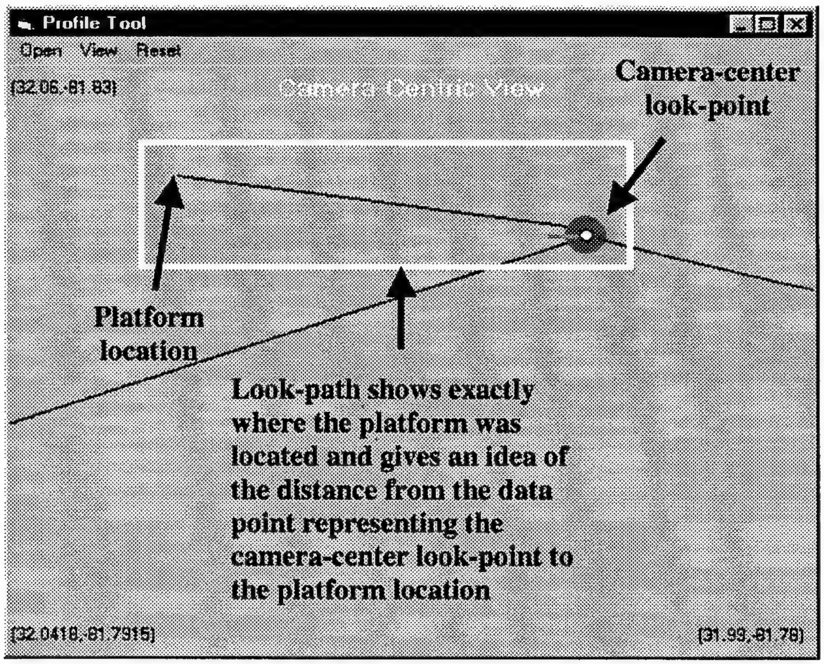


Figure 43: Look-Path for a camera-Centric Data Point

4.6 Minor Problems Encountered

The methodology proposed in Chapter 3 and the implementation described in the preceding paragraphs were affected by a few minor difficulties. While these difficulties occurred very infrequently and did not depreciate the overall value of this methodology, they are presented here as indicators of potential areas needing further research. The difficulties are presented below by degree of perceived severity. They include apparent

errors in telemetry records and missing telemetry records, imprecise target coordinates, and the affects of camera usage during the mission

4.6.1 Missing and Erroneous Telemetry Data

The supplied EFX telemetry files were plagued by missing telemetry records. In some instances the gap between telemetry records was as high as 11-seconds. This had the minor affect of diminishing the accuracy of identifying the temporal boundaries of target segments and the overall picture of how platform and camera were used during the mission. Although the system proposed and implemented by this research can accommodate missing records, more complete telemetry files will produce a more accurate picture of the mission and allow greater accuracy in locating targets identified in the target list. Sparse data may lead to targets not being identified if the remaining telemetry records do not record camera-center look-points falling within the .0003-degree threshold as discussed in Paragraph 4.5.2.

Another problem, although only occurring once, may indicate a more serious system problem requiring further investigation. In the instance under consideration, erroneous camera coordinates in the telemetry file caused the identification of a video segment for a target, but the target did not appear in the corresponding video. The problem arose because the camera coordinates of the erroneous record were close to the coordinates of the target. This resulted in the telemetry record being selected as the basis for a target segment index record. As a result, it appeared as though a video segment existed for the target. This was not the case, however, as was discovered by viewing the video corresponding to the erroneous target segment. In fact, the video footage showed

that the misidentified target never even entered the camera viewing area. Therefore, it was concluded that the coordinates in the telemetry record were invalid. This problem can be accommodated by either validating target segments against the video stream during population of the database or providing a capability to remove misidentified target segments through the user interface.

The image on the left of Figure 44 shows a video image corresponding to the time recorded in the erroneous telemetry record. Viewing the entire video sequence bears out that this is the same target as contained in the image on the right. The desired target is located Southeast of the target revealed in these images.

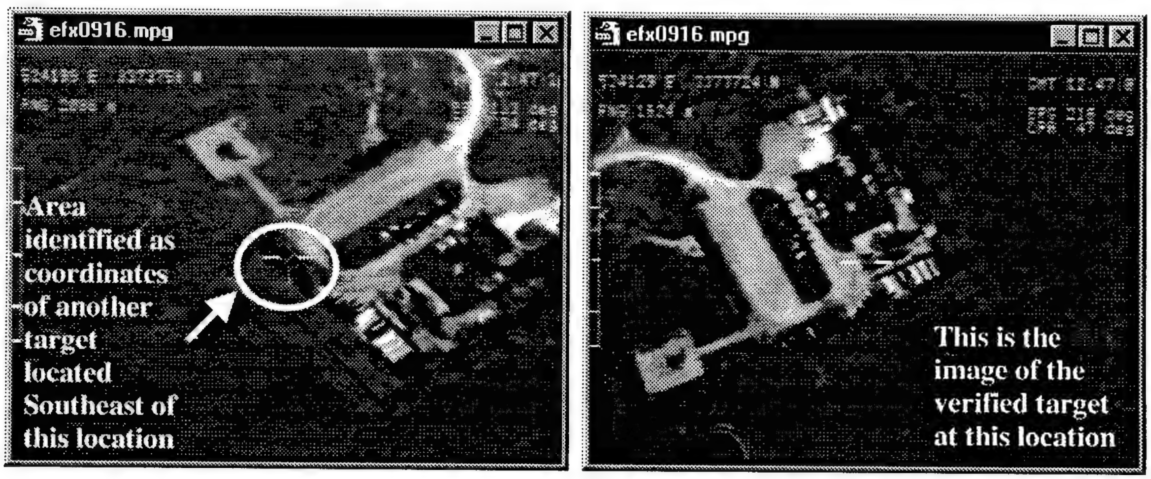


Figure 44: Images of Misidentified Target and Verified Target

4.6.2 Lack of Target Boundary Coordinates

The EFX-98 target data used in this research was characterized by each target being assigned a single geographic coordinate (latitude and longitude). There was no indication in the target lists of the geographic area the target covered. For example, a

building complex and a tank both had a single geographic coordinate specifying their respective locations. For small targets such as vehicles and single buildings, the target can be covered without moving the camera too far from the original target coordinates. In the case of a large target area, however, the camera may have to move significantly from the original target coordinates. As a result, by observing the telemetry stream, there is no precise way to determine when the target is no longer being recorded. This means a precise target-segment beginning and ending time can not be determined.

Imprecise target data was accommodated in this research by defining target-segments as having duration of 30-seconds. The time recorded in the telemetry record whose camera-center look-point coordinates were closer to the target coordinates served as the center of the 30-second period. When video associated with a target is selected through the query tool or profile tool, only this 30-second segment is initially presented to the user. The capability to backup or advance the video stream was incorporated into the application to allow the user to view all footage containing the target. Figure 45 demonstrates this problem and the imprecision of the workaround. Both images reveal portions of the target area that were not covered within the temporal bounds of the target segment. The omitted footage is observed by manually reversing or advancing the video past the segment's starting or ending points.

While more precision can be obtained with prior knowledge of the exact bounds of large targets, this knowledge may not always be available or feasibly attainable. Therefore the workaround described above is necessary in lieu of using complex target-recognition software to detect target presence in the video.

Figure 45: Lack of Target-Segment Coverage Due to Imprecise Target Coordinates

4.6.3 Effects of Camera Usage

The final minor problem involved the calculation of the distance between the camera-center look-point coordinates and the platform. In several instances, the distance calculation resulted in an extreme value. This situation resulted when the camera was nearly horizontal to the platform causing the camera-center look-point coordinates to register as a point on the horizon. This produced distance calculations in the hundreds of kilometers in some instances. Since the display for the profile tool is scaled using the coordinates of the camera-center look-points, the majority of the data points are often not plotted uniformly; rather they are bunched together as in Figure 46.

This problem can be overcome by training camera operators to keep the camera positioned towards the ground or by fast processing of telemetry to eliminate those records that exhibit these extreme distance values. In the latter case, no critical

information will be lost since the camera is not focused on the ground and the profile display will look better.

An argument against deleting the telemetry records as described above would be if proper camera and platform usage were being evaluated as in a training scenario. In these instances, deleting the records would hinder the evaluation process.

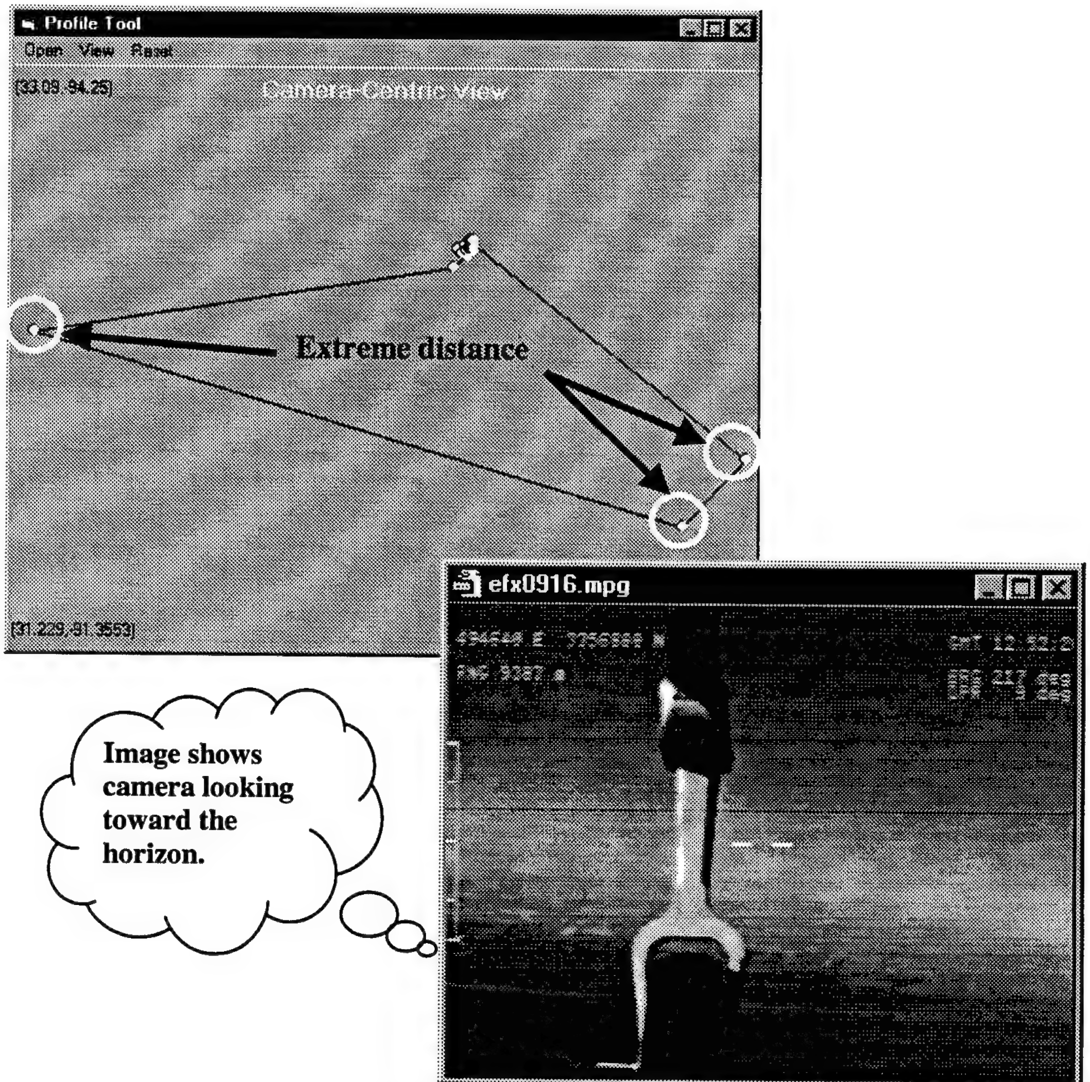


Figure 46: Extreme Distance Representation and Image

4.7 Conclusions

The objectives of this research as outlined in Table 1 have been realized with the implementation of the methodology presented in Chapter 3. It has been shown that telemetry and target data and calculated solar position can provide valuable indexes supporting random access into video streams recorded during UAV missions. A query tool such as the one developed for this research, supports target-centric retrieval of video segments. Alternatively, a profile tool supports visualization of platform and camera usage throughout the mission. This becomes valuable when evaluating platform and camera usage during the mission or when selecting video segments which may or may not contain images of a particular target.

The methodology presented in this research can be realized in a lightweight, portable application that can be executed from a laptop computer and a collection of CD-ROMs containing the digitized video files. Pre-loading the computer with indexed database tables and the application gives war-fighters in the field the ability to profile past UAV missions and rapidly locate and retrieve archived video segments. The knowledge gleaned from the system can assist evaluation of past missions, retrieval of archived video for comparison to recent video, or planning for future missions by identifying those areas or targets requiring a *second look.*

Chapter 5 will present recommendations for enhancing both the methodology and the implementation presented in this research. The recommendations are designed to enhance accuracy of the indexes, allow higher query granularity, and support the portability of the system.

5 CONCLUSIONS AND RECOMMENDATIONS

The focus of this research is to determine if mission-related data, such as telemetry and target data, and calculated solar position can provide the basis for indexing into the video stream as well as provide useful clues of video content. Chapter 4 demonstrates that this is the case. Four image-describing characteristics were derived from the mission-related data or calculated to demonstrate this capability: look-direction, solar illumination direction, look-distance, and zoom. This chapter summarizes the benefits of this research and provides recommendations for future research and enhancements to the methodology and implementation to make them more useful.

5.1 Benefits

Benefits in both operational and training support can be realized by this research. Operationally, the methodology presented in this research offers relief from serial searching of video to find segments or images of interest. Analysts will now be able to access video streams at any temporal point based on target information, image characteristics, or flight path coordinates. Additionally, they will be able to select video segments of identified targets offering the *best* images (images with the greatest degree of image detail) from a collection of videos containing footage of the same area. Depending on the number of missions flown over the same area, this could dramatically reduce the time required to locate and retrieve desired video images.

A second benefit to be realized by this research is in the area of mission analysis and evaluation. By reviewing a graphical profile of the mission, camera and platform usage can be rapidly analyzed and evaluated. Insufficient sensor coverage of a target area, less than optimal view of the target, and approaching too close to a *hot* target are instances of the types of information which can be quickly ascertained through the use of the mission profile presented in this research. Although only four image-describing attributes were used in this research, other attributes exist in the telemetry stream that could prove useful to a complete analysis of the platform and camera usage during a mission. These include, among others, camera depression, platform altitude, and heading. Each of these could be incorporated into the profile to provide a more complete picture of sensor and platform configuration throughout the mission.

5.2 Recommendations

Although the benefits described above are realizable in the methodology presented in this research, steps can be taken to increase the accuracy of the indexes, introduce more indexes, reduce the storage requirements of the system, and enhance the presentation of information to the user. These steps include establishing a dynamic distance threshold for identifying target-segments, using voice tapes to improve the accuracy of target segment boundaries and introduce new indexes, using digital versatile disk (DVD) technology to reduce video storage requirements, and using mosaics rather than full-motion video to present video images to users. Each of these recommendations are presented below.

5.2.1 Dynamic Distance-Threshold

For this research, only one set of target and telemetry data was available for the same mission: EFX-98. The distance-threshold (.0003-degrees) for determining if a telemetry record contained information about a target was derived through experimentation. The lower bound was established when all targets identified in the target list for the mission in question were associated with at least one telemetry record. It is hypothesized that the lower bound will be related to the height of the platform and the range from target to platform. Since platform height did not vary when the platform was over a target, this hypothesis could not be tested. It is recommended that this hypothesis be researched further with the intent of establishing a dynamically configurable lower bound on the threshold as a function of platform height and range to target.

5.2.2 Mission-Related Audio Tapes

Another recommendation that could improve the accuracy of current indexes and introduce new indexes involves the use of mission-related voice tapes. These tapes may offer useful information about the exact location of targets or other image-describing characteristics. If audio indications are made when the camera enters and leaves a target area, the temporal boundaries of target segments can be more accurately defined (assuming the audio, video, and telemetry are temporally synchronized). Audio recordings may also provide descriptive information about the target itself such as orientation (tank pointed North), size (3-story building), or color (blue truck). This

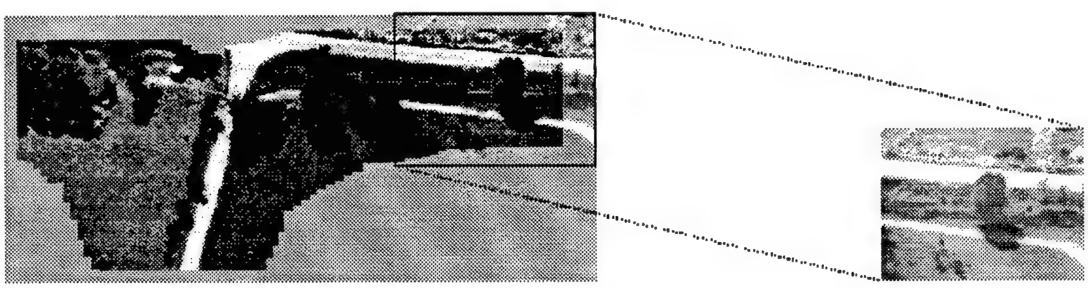
information provides attributes that assist in target identification and should be extracted and indexed to provide finer query granularity.

5.2.3 DVD Technology

A third recommendation involves the storage medium and compression standard used for digitized video streams. Currently, mission video is stored as MPEG-1 files on CD-ROMs with a maximum capacity of 640 MB. By storing video files in MPEG-2 format on DVDs, the storage capacity can be increased to over 4 GB per recording layer per disk surface (see Chapter 2 for a discussion of how data is stored on DVDs). Four gigabytes of MPEG-2 compressed video equates to over two hours of high-quality video. Therefore, approximately eight hours of MPEG-2 video can be stored on one DVD disk as opposed to a maximum 1.3 hours of MPEG-1 video on CD-ROMs. This increase in storage capacity reduces the number of disks that would be deployed with a portable system and greatly reduces the number of disks required to hold the digitized video footage of all missions. Although the move to DVD technology is advantageous, care must be taken to ensure the DVD hardware is capable of reading CD-ROMs since there will likely be a large amount of video-data stored on this medium--[TAYLO98] points out that about half of the *first-generation* DVD drives can not read the commonly used CD-R disks and no CD-ROM drive can read DVD disks. It is anticipated that when the move is made to DVDs, the most current technology will be procured thus making this a non-issue. Therefore, it is recommended that a migration path from CD-ROM to DVD technology be determined.

5.2.4 Mosaics

One of the challenges of full-motion video exploitation lies in how to present the images to the user in such a way as to maximize comprehension of the information. One of the effects that minimizes comprehension is known as the *soda straw* effect. This is caused by having only a localized view of the video information presented in each frame. To reduce the normal *soda straw* effect, a portion of video can be viewed as a mosaic of images. This *birds-eye* view increases spatial comprehension of the data allowing more accurate analysis of the information. Figure 47 demonstrates this by showing how more information is available to the viewer in a single mosaic image than can be relayed by a single video frame.



A B

Figure 47: Mosaic Image (A) Revealing More Information than a Single Frame (B)

Although there are many benefits to using mosaic images rather than full-motion video, [PAGE99] points out that certain types of camera-motion and video characteristics hamper the mosaic-building process used in current software. Among these are zooming

and tilting of the camera, dramatic differences in content between sequential frames, and bad frames caused by poor camera exposure or environmental conditions (sun glare, poor illumination, etc.). However, this should not deter efforts to capitalize on this technology when the video supports the mosaic-building process as when the camera is *panning* an area. It is recommended that, when the data supports it, mosaics be built for video segments containing targets identified in target lists. When the user wish to see a target segment, the mosaic should be presented. Target segments for which a mosaic could not be built should be returned as full-motion video as described in this research.

5.3 Summary

Based on the results presented in Chapter 4, the methodology presented in this research performs favorably to assist in the rapid location and retrieval of video segments of interest. Additionally, the profiling of mission data provides an informative representation of how platform and camera were utilized throughout the mission. This provides the basis for the evaluation of platform and camera usage during the mission as well as retrieval of any user-specified segment of video. To enhance these capabilities and to provide for the conservation of resources, several recommendations are made. These include introducing a dynamic distance-threshold for determining when a telemetry record contains information pertaining to a target, using voice tapes to gather more information about a target or viewing area, using DVD technology to reduce storage requirements, and, where possible, providing mosaics of target areas to increase information understanding and analysis.

APPENDIX A – DATA AND SOFTWARE AVAILABILITY

The data and software used in this research is available by contacting the AFIT School of Engineering and Logistics Database Systems Research Point of Contact (POC). Currently, the Database Research POC is:

Major Michael L. Talbert, Ph.D.
Air Force Institute of Technology
WPAFB, OH 45433-7765

Email: michael.talbert@afit.af.mil
Phone: DSN 785-6565 ext. 4280 COMM (937) 255-6565 ext. 4280

BIBLIOGRAPHY

[ACCCO98] Department of the Air Force. *Air Combat Command Concept of Operations for Endurance Unmanned Aerial Vehicles*. Virginia: HQ ACC, 1 April 1998.

[ALBER96] Albers, Bryan J., Jonathan E. Nyquist, and Caroline B. Purdy. "The Department of Energy's Use of Airborne Remotely Piloted Vehicles for Environmental Management," *AUVSI '96 Proceedings*, Orlando, Florida. 839-847.

[ARMY99] Army Corps of Engineers. *Corpscon for Windows*. Shareware Version 5.11.03, *http/www/crunch.tec.army.mil/ software/corpscon/corpscon.html.* 1997.

[BOLLE98] Bolle, R. M., B. L. Yeo, and M. M. Yeung. "Video Query: Research Directions," *Journal of Research & Development, Vol 42, No. 2*: 1-22 (August 1997).

[BRONE97] Bronez, Thomas P., and Elizabeth S. Hughes, "Image & Video Retrieval for National Security Applications: An Approach Based on Multiple Content Codebooks." Unpublished Report No. MP 97W, Project No. 51CCG89JC4. MITRE Corporation, McLean VA, June 1997.

[CARVE54] Carver, Harry C. *Distance and Azimuth Computations with Tables*. Ann Arbor: Edwards Brothers, Inc., 1954.

[CONGR98] Congressional Budget Office. "Options for Enhancing the Department of Defense's Unmanned Aerial Vehicle Programs." Report to Ranking Minority Member of the Senate Committee on Armed Services, Washington DC. September 1998.

[DAZZL97] DAZZLE™ Multimedia. *SNAZZI*. Video Capture Software, *http//www.dazzlemm.com.sg/html/snazzi.html*, 1997.

[DELBI99] Del Bimbo, Alberto. *Visual Information Retrieval.* San Francisco: Morgan Kaufmann Publishers, 1999.

[GRIFF96] Griffioen, James, Raj Yavatkar, Robert Adams. "Automatic and Dynamic Identification of Metadata in Multimedia," *First IEEE Metadata Conference*, Silver Springs, MD. 1996.

[GRONB99] Gronbeck, Christopher. "Sun Position." Excerpt from online Java script instructions and tutorial. *http//www.susdesign.com.* 20 October 1999.

[HANSE98] Hansen, Steve. "Automated Spatio-temporal Archiving and Retrieval of Unmanned Air Vehicle Full Motion Video (Draft)," Unpublished report. MITRE Corporation, McLean VA, 3 February 1998.

[HOVER99] Hoversten, Paul. "Pilotless Planes may soon take Flight," Excerpt from USA Today Tech Reviews. n. pag. *http//www.usatoday.com/lif/cyber/tech/review/crg469.htm.* 23 November 1999.

[KINDR98] Kindred, Darrell. *Perl Script to Calculate Distance and Azimuth.* Public domain source code. Darrell Kindred <dkindred@cmu.edu>, 1998.

[MATRO99] Matrox Electronics Ltd. *Matrox PC-VCR Remote.* Video capture software. *http//www.matrox.com/videoweb/ home.html,* 1999.

[NIBLA93] Niblack, W., R. Barber, W. Equitz, M. Flickner, E. Glasman, D. Petkovic, P. Yanker, C. Faloustos, and G. Taubin. "The QBIC Project: Querying Images by Content Using Color, Texture and Shape," *SPIE* 1908: 13-25 (February 1993).

[NYQUI96] Nyquist, Jonathan E. "Applications of Low-Cost Radio-Controlled Airplanes to Environmental Restoration at Oak Ridge National Laboratory," *AUVSI '96 Proceeding*, Orlando, Florida. 817-829. 1996

[PAGE99] Timothy I. Page, *Incorporating Scene Mosaics as Visual Indexes into UAV Video Imagery Databases.* MS Thesis, AFIT/ENG/GCS/99M-16. School of Engineering and Logistics, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 1999.

[PENDE96] Pendergast, M. M. and K. J. Hofstetter. "Application of UAV's at the Savannah River Site," *AUVSI '96 Proceedings*, Orlando, Florida. 803-816. 1996

[PEREZ96] Perez-Lopez, Kathleen, Brian Krasner, and Gregory Baraghimian. "Smart Metadata for Content-based Retrieval from Large Image Databases," *First IEEE Metadata Conference*, Silver Springs, MD. 1996.

[POPE98] Pope, Arthur, Rakesh Kumar, Harpreet Sawhney, and Charles Wan. "Video Abstraction: Summarizing Video Content for Retrieval and Visualization," *Thirty-Second Asilomar Conference on Signals, Systems, & Computers*. 915-919. 1998.

[PRATT86] Pratt, Timothy and Charles Bostian. *Satellite Communications*. New York: J. Wiley, 1986.

[ROWE94] Rowe, L. A., J. S. Boreczky, and C. A. Eads. "Indices for User Access to Large Video Database," *SPIE*, 2185: 150-161 (February 1994).

[STILW95] Stilwell, James E. "Cattle Herding to Drug Enforcement: Civil Uses for Ultra-Intelligent Autonomous Air Vehicles," *AUVS '95 Proceedings*. 567-573. Arlington: Association of Unmanned Vehicle Systems, 1995.

[TAYLO98] Taylor, Jim. *DVD Demystified.* New York: McGraw-Hill, 1998.

[VIZAR99] Vizard, Frank. "Spy in the Sky," *Popular Science*: 74-75 (January 2000).

VITA

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After graduating from Basic Training at Lackland AFB, TX, he served as a Supply Specialist at Cannon AFB, NM (May 1984 – Jan 1986) and Eielson AFB, AK (Jan 1986 – Jan 1990). In January 1990, he entered the Communications-Computer Technical Training School at Keesler AFB, MS as a cross-trainee. His new career field would take him to US Strategic Command at Offutt AFB, NE.

While stationed at Offutt, Captain Berridge completed the requirements for a Bachelor's degree from the University of Nebraska at Omaha. He graduated Magna cum Laude with a degree in Computer Science/Mathematics in October 1994. After graduation, Captain Berridge was accepted to Officer's Training School at Maxwell AFB, AL, where he graduated as a Distinguished Graduate in March 1995. From OTS, he was assigned to the 50th Logistics Support Squadron at Schriever AFB, CO where he served as a UNIX System Administrator in support of the Air Force's Satellite Communications Network.

Captain Berridge's military awards include the Joint Service Commendation Medal, the Air Force Commendation Medal with one oak leaf cluster, and the Air Force Achievement Medal. He is married to the former Melisha C. Humble of Bay, AR, and they have two children: Nathan and Brandon.

Captain Berridge is currently assigned to Wright-Patterson AFB, OH, where he is attending the Air Force Institute of Technology working on a graduate degree in Computer Systems. Upon graduation in March 2000, he will be assigned to Arnold Engineering Development Center (AEDC), Arnold AFB, TN.

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ABSTRACT (*Maximum 200 Words*)

With the acceptance of Unmanned Aerial Vehicles (UAVs) as a primary platform within the Department of Defense (DOD) for gathering intelligence data, the amount of video information being recorded, analyzed, and archived continues to grow. Mechanisms for quickly locating and retrieving video segments of interest amongst the many hours of recorded video are required to accommodate the rapid turnaround expected in today's wartime planning environments. This research demonstrates that text-based data accompanying UAV video yields sufficient information to identify data items that can be indexed for rapid identification and retrieval of video segments. Four attributes are derived or calculated from mission-related telemetry and target data: look-direction, look-distance, zoom, and solar illumination direction. These attributes provide indicators of potential scene characteristics, scene detail, and image quality thus allowing analysts to select the clearest, most detailed images of a target or target area. Two tools, a query and profile tool, are implemented to provide for the retrieval and presentation of video segments to the user. An analysis of the results shows the methodology discussed in this paper to be favorable for locating and retrieving video segments of interest.

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